

NOV 5 1928

SCIENCE

NEW SERIES
VOL. LXVIII, No. 1766

FRIDAY, NOVEMBER 2, 1928

ANNUAL SUBSCRIPTION, \$6.00
SINGLE COPIES, 15 CTS.

A NEW TEXT-BOOK

Greaves' Elementary Bacteriology

PERIODICAL ROOM
GENERAL LIBRARY
UNIV. OF MICH.

DR. GREAVES has created a text-book on bacteriology that is modern in treatment, well illustrated and in every way a most desirable text for courses in elementary bacteriology. The author clearly illuminates the subject of bacteriology from all its angles, throwing light upon the beneficial and the harmful bacteria, and giving the most modern methods of their control.

The fundamentals are presented fully and interestingly. Dr. Greaves discusses the early ideas and theories, the work of the pioneers, the discovery of bacteria, and other historical phases that build up the student's interest, show him the importance of the subject, and give an easily and quickly acquired foundation for the study. This historic material is followed immediately by chapters devoted to the study of actual bacteria—their classification, form, chemistry, food requirements, products, etc.

The remainder of the book (*over one-half*) is devoted to a discussion of the tremendous part bacteria play in the world of man. Here Dr. Greaves shows the actual relation of bacteria to life, and the direct application of the study in the various arts and industries. These are pointed chapters, wasting no words in generalities, but telling in clear fashion just how bacteria work to man's benefit or harm. Separate chapters are devoted to bacteriology in the various diseases and to such allied subjects as immunity, antitoxins and vaccines, etc.

By Joseph E. Greaves, M.S., Ph.D., Professor of Bacteriology, Utah Agricultural College, Logan. 12mo of 506 pages, illustrated. Cloth, \$3.50 net.

..... SIGN AND MAIL THIS ORDER FORM TODAY

W. B. SAUNDERS COMPANY, West Washington Square, Philadelphia

Please send me Greaves' Elementary Bacteriology, and charge the \$3.50 to my account.

NAME ADDRESS

A History of Mathematical Notations

in two volumes

by

FLORIAN CAJORI

Volume I—Elementary Mathematics, now ready. \$4.00

Volume II—Advanced Mathematics, in preparation. \$6.00

This study emphasizes the difficulty experienced even in ordinary arithmetic and algebra in reaching a common world-language. The only hope for rapid approach of uniformity in mathematical symbolism lies in international co-operation through representative committees.

SEND FOR COMPLETE CATALOG

The Open Court Publishing Company

339 East Chicago Avenue
Chicago, Ill.

The Teaching of Science and The Science Teacher

A practical manual for science teachers, by Herbert Brownell and Frank B. Wade.

Says William McAndrew in *The Educational Review*, "It is inspiring to read in this book the call to make the study of science a developer of productive conduct and character."

"Should be in the library of every science teacher"—*Science News-Letter*.

"We heartily recommend this book to science teachers"—*New Jersey Journal of Education*.

The Century Company

353 Fourth Avenue, New York City
2126 Prairie Avenue, Chicago

The Wistar Institute Bibliographic Service

is of invaluable assistance to

Librarians—Investigators—Teachers

It brings to them, in AUTHORS' ABSTRACT form, a brief review of all original papers on Biological Subjects which appear in the following journals:

Journal of Morphology and Physiology
The Journal of Comparative Neurology
The American Journal of Anatomy
The Anatomical Record
The Journal of Experimental Zoology
American Journal of Physical Anthropology
The American Anatomical Memoirs
The Biological Bulletin (M. B. L., Woods Hole, Mass.)
Folia Anatomica Japonica (Tokio, Japan)
The Journal of Parasitology (Urbana, Ill.)
The Australian Journal of Experimental Biology and Medical Science (Adelaide, South Australia)
Stain Technology (Geneva, N. Y.)
Physiological Zoology (Chicago, Ill.)

Advance Abstract Sheets

issued every few days, bearing Authors' Abstracts without bibliographic references, offer a practical means of making research immediately available in abstract form and of purchasing articles of special interest in reprint form without the necessity of subscribing to all the journals. Subscription, \$3.00 per year.

Bibliographic Service Cards

with complete bibliographic references, printed on Standard Library-catalogue cards, are of value and assistance to Librarians and Investigators. Subscription, \$5.00 per year.

Abstracts in Book Form

referred to above, are brought together periodically, with Authors' and Analytical Subject Indices. Price \$5.00 per volume.

Subscriptions to the Bibliographic Service and orders for reprints should be sent to

The Wistar Institute of Anatomy and Biology
Thirty-sixth St. and Woodland Ave. Philadelphia, Pa.

PHOTO-ELECTRIC CELLS THE BURT CELL

Without Fatigue—Highly Sensitive
Absolutely Reproducible—Instantaneous in Response

The BURT-CELL is made by a new method and should not be confused with any other photo-electric cell. By a special process of electrolysis, the photo-electric metal is introduced into a highly evacuated bulb directly through the glass wall of the bulb, giving photo-electric material of absolute purity. The superiority of the BURT-CELL is due to these features, making possible results never before obtainable.

Described in Bulletin No. 271

QUARTZ CELLS—We are pleased to announce that we are manufacturing reproducible quartz photo-cells for measurement of ultra-violet.

We also manufacture the **STABILIZED OSCILLOSCOPE**—the only **VISUAL OSCILLOGRAPH** having a linear time axis and no inertia—giving an accurate picture of high frequency wave forms. This is a most powerful tool for the study of periodic phenomena.

Write for Bulletin 273

DR. ROBERT C. BURT

Manufacturing and Consulting Physicist
327 S. Michigan Ave., Pasadena, Calif.

SCIENCE

VOL. LXVIII

NOVEMBER 2, 1928

No. 1766

CONTENTS

<i>Physics and Vital Processes</i> : PROFESSOR W. F. G. SWANN	411
<i>Fractures and Fiords in the Faeroes</i> : PROFESSOR W. M. DAVIS	419
<i>Scientific Events</i> :	
<i>The Fauna of the British Empire; A New California Wild-life Refuge; Summer Meeting of the American Society of Plant Physiology; Appropriations for Research at Cornell University</i>	420
<i>Scientific Notes and News</i>	423
<i>University and Educational Notes</i>	425
<i>Discussion</i> :	
<i>A Bacteriolytic Principle from the Root Nodules of the Leguminosae</i> : DR. E. R. HITCHNER. <i>Effects on Pisum sativum of a Lack of Calcium in the Nutrient Solution</i> : DR. DOROTHY DAY. <i>Thermal Conductivity of Glasses transmitting Ultra-violet Light</i> : WILLIAM KUNERTH and WILLIAM E. BERKEY. <i>Cacoëpistic Scientific Terms</i> : DR. W. A. HAMOR. <i>"Isorropic"</i> : E. M. BLAKE. <i>Prickly Pear Control in Australia</i> : PROFESSOR GLENN W. HERRICK	426
<i>Quotations</i> :	
<i>The National Academy of Sciences and Harvard University</i>	428
<i>Scientific Books</i> :	
<i>Die Saeugethiere</i> : DR. W. D. MATTHEW. <i>Der Sauerstoff im Eutrophen und Oligotrophen See</i> : PROFESSOR C. JUDAY	429
<i>Scientific Apparatus and Laboratory Methods</i> :	
<i>A Photographic Method of measuring Pitch</i> : DR. MILTON METFESSEL	430
<i>Special Articles</i> :	
<i>Iodine and Iron in a Vitamin A Free Diet</i> : PROFESSOR F. E. CHIDESTER, A. G. EATON and G. P. THOMSON. <i>A Genic Disturbance of Meiosis in Zea mays</i> : GEORGE W. BEADLE and BARBARA MCCLINTOCK. <i>The Elimination of Carbon Dioxide in the Insecta</i> : DR. W. H. THORPE	432
<i>Science News</i>	x

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal.
Lancaster, Pa. Garrison, N. Y.

Annual Subscription, \$6.00. Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

PHYSICS AND VITAL PROCESSES¹

NEVER before have I attempted to give a lecture on a subject about which I know as little as I do about the physics of vital processes. Those who did me the honor of inviting me to speak should, however, be better acquainted even than I am with the probable extent of my ignorance, so that I hope you will follow the custom of a certain English college which, when one of its members invited a guest to its dining halls, recorded to the credit of the host any offenses committed by his guest, and fined him accordingly.

I should indeed hesitate to attempt any critical discussion of special fields of biophysics in the presence of an audience many of whose members are far more competent to discuss these matters than I am. Nevertheless, when a physicist turns his attention to the mechanism of things which pertain to life he is apt to be impressed by certain aspects of a general nature which may have seemed of secondary importance to the biologist, but which, nevertheless, in his own eyes play a very fundamental rôle. This is particularly the case in these days when the physicist has become humbled in the matter of materialistic dogma by his endeavors to understand the actions of the most capricious thing in all nature, not excepting the things which live, nor even the female sex thereof, by his endeavor to understand the atom.

We may divide the activities of living things into three classes as regards their relation to physics. First, we have the class which is understandable to us in terms of physics or chemistry, without the invocation of laws other than those which have become familiar to us in the laboratory. Thus, when I expand my chest, I require no further knowledge than the fact that the pressure in a space decreases when the volume increases to explain why my lungs fill with air. When I observe that the boundary of the protoplasmic interior of the cell allows certain things to pass through and stops others—when I find that the cell can build up within itself a hydrostatic pressure greater than that in the medium in which it is placed, I am not surprised, because I can duplicate such phenomena with various membranes in the laboratory. Even though I may be unfamiliar with the complete theory of osmosis in its molecular aspects, I am ready to accept the facts as understandable in

¹ Presented at the American Chemical Society Institute, Northwestern University, Evanston, Illinois, August 11, 1928.

terms of physical laws, just as I am satisfied as to the reason for the transmission of vibrations through this table when I strike it, although, until we have a more satisfactory theory of cohesion and of the nature of intermolecular forces than we have at present, I shall not see in all its details the ultimate reason for the transmission of motion from one part to the other.

One of the first questions which must confront the biophysicist in the examination of any class of phenomena is that of deciding how far these phenomena can be explained as regards their detailed action without the invocation of processes other than those which can be produced in the laboratory with non-living matter. I may cite one or two illustrations of this kind.

I was once consulted by a biologist concerning the conductivity which appeared to be imparted to a solution by the presence of certain spores in suspension. From the point of view of the physicist, the first thought is that the phenomenon may have a very simple explanation; for, if we should place a number of small conducting spheres in a liquid, they would distort the flow of the electric current and would so alter the apparent conductivity to an extent depending upon their size and number. Even if the spheres were insulating, or imperfectly conducting, they would produce an apparent alteration in the conductivity calculable in terms of the relative conductivities and dielectric constants of the materials of the spheres and medium, and in terms of size and number of the spheres per cc. By making measurements of different kinds it is possible to dissect out the values of the various quantities which would thus participate in a physical explanation of the phenomenon and make a test of the consistency of our hypothesis.

But it was found that the effect of the spores on the conductivity changed when they died. At first sight this fact would seem to imply some phenomenon having to do with the life of the cell. A closer examination of the situation showed, however, that the size of the spores changed at death, so that before one is driven to the necessity of postulating anything out of the realm of his physical understanding, it is necessary to see whether this changed size alone is sufficient to account for the change of conductivity, or if there is any change in the conductivity or dielectric constant of the spores' interior which is sufficient to account for the change observed.

The quantitative aspect of physical phenomena is one which should not be lost sight of by the biologist. When one speaks of organisms as being charged and seeks to account thereby for certain lively motions which they exhibit in relation to each other, it is well to remember that, in the simple sense of our under-

standing of the phenomena, a charged body placed in a solution of the conductivity prevailing in the solutions in which these actions usually take place would lose 90 per cent. of its charge in a small fraction of a millionth of a second. It is true that a body can acquire a charge when placed in a liquid, this charge being associated with the difference of potential which becomes set up between the body and the liquid. But the charged body becomes surrounded by a layer of opposite charge in the liquid in its immediate vicinity, so that the electric field of its charge does not extend out in the simple manner associated with a charged body in empty space. The story of its motion under the influence of electric forces is not a very simple one. It would therefore seem that in all discussion drawing upon the repulsion of charges in liquids, matters should be pushed to their quantitative conclusions, at any rate as far as the knowledge of the physical data will permit.

The second class of phenomena comprises those which have not been duplicated in the laboratory in such a manner as to provide a quantitatively satisfactory explanation of the actions of the organism, but in which an appeal is made to possible specialized conditions of matter in the living cell as the cause of the enhancement of activity of the purely physical mechanism.

Thus, many chemical reactions which take place in the non-living protoplasm occur with increased velocity in the otherwise indistinguishable living protoplasm.

Again, while osmosis is not a phenomenon peculiar to the living state, the osmotic properties of the cell membranes are profoundly modified when the cell is living.

In this class of phenomena it remains to be definitely proved as to whether we need invoke any principles other than complexity of chemical or physical structure to account for the apparently special characteristics of living matter.

Finally, we have the third class, if indeed there be such a class, which comprises those phenomena of life which require a definite appeal to a wider system of laws than those comprised under chemical or physical laws in the ordinary sense of the words.

Speaking of cohesion, Sir Oliver Lodge once remarked that it was as yet an inexplicable fact that when one end of a rod is pushed the other end moves, to which *Punch* retorted that it was an equally inexplicable fact that when one end of a man is trodden upon the other end shouts. Now as to whether the phenomenon cited by the famous comic periodical is more or less wonderful than that cited by Sir Oliver Lodge is a function of what the other end says. Inso-

far as the action is purely reflex, I suppose it is no more wonderful. Even if the victim should say damn from force of habit it is no more wonderful. But if he says damn for the first time, then I think the phenomenon is more wonderful, because it includes as much as was included in the problem of the rod and also something more: it means that a definite physical phenomenon, the production of the state of air motion associable with the propagation there-through of the objectional expletive which I have already cited twice was brought about as the result of an intention initiated in the brain.

From the standpoint of the physics of the last century, at any rate, such a phenomenon attains the status of a miracle, whose degree of remarkability can be gauged only by a detailed tracing of the physical mechanism back step by step to the origin of its inception in the brain.

The very essence of a physical law in the sense of a half a century ago lies in its providing a definite statement of the subsequent behavior of a system when the condition of the system is appropriately stated at some instant. Consider, for example, the Newtonian law of gravitation as applied to a number of bodies moving about in space. I know that if I should come upon these bodies in certain positions and start them off afresh with certain velocities, their subsequent history for all time would be determined by the Newtonian law. The answer given by the law to a question asking the state of the system at any subsequent instant would be perfectly definite. It might even be wrong, but it would be definite.

Now in order to give these bodies the velocities which I actually imparted to them I had to do something. If, at the instant when I was about to touch those bodies, I had refrained and left them to themselves, the velocities which they would have had at the next and subsequent instants would have been those determined for them by the law of gravitation as a result of their previous history. To postulate that they of their own accord would suddenly change their velocities in a manner which disregarded what the law of gravitation had to say about the matter would be to postulate a miracle—a temporary suspension of the activities of the general law. The new state of motion resulting from the miracle would not itself be inconsistent with the general law once it had been produced. The inconsistency would be confined to the act of its production.

I temporarily relieve myself of the necessity of postulating a miracle by saying that I took hold of the bodies and threw them into space with the velocities in question; but having committed myself thus far, I must now go on and trace again by some appropriate

laws the actions of my hands in approaching these bodies, of catching hold of them, and of imparting to them their velocities. I can go back into the history of the matter for some distance without encountering any grave philosophical difficulty. This motion of my hand and the subsequent grip upon the bodies was determined by forces brought into play on account of my muscles, so that granting the contractions of the muscles there is a train of laws providing in continuous manner for the history of the matter up to and including the impartation of the motion to the bodies, the continuity being thereafter perpetuated through the law of gravitation. But I dare not stop at the contraction of the muscles without relating that to something else, for, if I do, I introduce a miracle, which I wish to avoid, so I look further into the mechanism of the contraction.

I see that it is associated with certain chemical changes in the muscles, so that the path from the chemical changes to the contraction of the muscles is probably understandable in terms of physical and chemical processes. But the chemical changes were not of the kind which took place spontaneously, as, if they were, it would be a fact that all beings possessing muscles would be involuntarily constrained by those muscles to do the same experiment that I have imagined myself to have done. And so I invoke the nerve stimulus to the muscle as a link to continue the train of law action back from the muscle. Then I refer the nerve stimulus back to the brain, and there I must pause; for, at this point, two courses are open to me. I may suppose that the action in the brain was the outcome of what occurred before and that, pursuing this matter back step by step to its logical conclusion, there was somehow or other contained in the state of the universe a thousand years ago the inevitable consequence that to-day I should carry out the experiment which I have cited.

Now such a picture of the habits of the universe is not one which lends itself to our liking. It represents the doctrine of predetermination which the philosophers have wrangled over for many a long year. Yet, the only alternative is the postulation of a sudden suspension of the ordinary physical laws, by which new "initial conditions," as the student of dynamics would call them, are created, leading by subsequent operation of the general law to actions of the individual different from those which would have occurred if there had been no discontinuity in the state of the system. Perhaps it would be better to avoid the use of the term "suspension" of the ordinary physical law and widen our concept of what a physical law is to include the possibility of such discontinuities as part of it. In such a conception of the actions of the

universe we would think of the condition of a system as being determined by some general law in the step-by-step fashion, each step being governed by its immediate previous history, but we should think of its being determined in this way only over finite intervals of time, these finite intervals being separated from each other by sharp boundaries of discontinuity in which new alignments of the quantities which specify the system take place, these alignments being provided for in general by conditions quite apart from the general continuous law which guides the system over the intervals between its discontinuities.

I do not wish to imply that these discontinuities are necessarily unrelated to anything, but only that they are not to be expressed in a unique manner or as an inevitable consequence of the previous state of the system. Were they so expressible our laws would simply revert to the old doctrine of predetermination in a more elaborate form.

The essence of the assumptions involved in the introduction of these discontinuities is that, at any given state of the system, there shall be not one but many different kinds of discontinuity which may occur, and that if the state of the system plays any part in the matter at all, it is in determining the relative probabilities of the occurrence of the different kinds of discontinuity.

There may be discontinuities which are spontaneous in the sense that the probability of their occurrence is not related in any obvious manner to the state of the system. One is naturally tempted to associate spontaneous thoughts with such discontinuities. My decision to do the experiment which I cited earlier is a case in point. If I do the experiment because you ask me to, we have a case where the spontaneous discontinuity which represented the thought in your brain produced a physical phenomenon, your speech, for example, which increased beyond its normal amount the probability of that discontinuity in my brain which is to be associated with the initiation of the experiment.

The element of probability as distinct from certainty in the matter of the initiation of these discontinuities is illustrated by what would happen if you should tread on my toe. The discontinuity may be such as to give rise by a train of continuous processes to actions in my muscles which will cause me to knock you down. Or it may be of such a kind as to lead ultimately to the muscles of my lungs and tongue and cause me to swear at you.

Spontaneous thoughts, *i.e.*, those associated with discontinuities which have no simple relation to the state of the system or to physical causes resulting from discontinuities in external systems, are naturally

to be associated with free will actions. The philosopher may object that if they are purely spontaneous they deny by their very nature the doctrine of free will. The question here involved is, however, merely one of words. The essential thing about free will actions is their unrelatedness to anything, or at any rate the lack of uniqueness in any relation which they may have to external causes. I may strike you or hurl maledictions at you when you tread on my toe, but there is no certainty of either, that is all. The additional aspect which presents itself, and concerned with whether I could have done anything other than what I did do, has to my mind no meaning. Of the various possibilities, one has happened. The occurrence of that one is not the result of my choice, it is my choice. Of course we must admit that developments may take place in my system which cause the probability of some discontinuity A to be greater than that of B. I may even develop to a state where I fail to respond at all to a certain stimulus in the matter of initiation of discontinuities of certain kinds. I may neither swear nor fight when you tread on me. And this development may even be initiated by outside stimuli—the attempt on your part to convert me to a righteous behavior.

According to the foregoing views then, these discontinuities which symbolize the initiation of the various actions—the blow, the emission of bad language, the intention to perform an experiment, and so forth—constitute the essential distinctions between living and non-living matter; and the vital feature of these discontinuities is that they are not related to the state of the system or to outside influences in such a manner as to make the occurrence of any one of them a certainty under any specified conditions. All that the outside influences or the state of the system can determine for any kind of discontinuity is a certain probability of its occurrence.

I should like to illustrate some of the foregoing remarks by considering a simple example which may serve as a crude parallel in discussing some of the questions pertinent to living matter.

Suppose I have a set of balls moving about in this room, subject only, let us say, to Newton's law of gravitation. The types of motion which I shall observe will depend upon that law and upon the particular state of the system at some instant; or, put more crudely, upon the particular types of motion which were started. It may be that I shall find all the balls arranged in concentric rings about a central ball, each of them whirling around the central ball as planets whirl about the sun. Suppose that in another room I have another set of identically similar balls moving under the same law of gravitation, but

started off in a different way. It may be that I shall find those balls separated off into little groups, each of which is like a miniature solar system of its own, and possibly some of the balls may dance around these groups like comets visiting various solar systems. In other words, I may have in rooms A and B identically similar balls, obeying the same general law, but resulting in conditions which are entirely different in the two rooms. Some of the phenomena in A may be entirely unknown in B, for the reason that they could not have evolved by continuous application of the gravitational laws out of the particular state of the system originally initiated in B. It would not be anything about the general physical law which determined the difference between the conditions in A and B, but simply what the mathematician calls "the initial conditions." Indeed, we may have an infinity of different systems of identically similar objects all agreeing with one and the same general law which is sufficient to determine their state at any instant from that at a previous instant, and yet showing properties which have no apparent relation to each other. Suppose now that there should occur in one of our systems A and B a miracle, or, to use a less disturbing phrase, suppose that there becomes initiated one of those discontinuities in state to which I have already referred. Then it is possible that, following this discontinuity, the system will continue to obey the same laws as before, but show characteristics quite different from those which it had formerly exhibited.

In this crude example of the balls moving under gravitation may we not have a possible, even though a remote, parallel to the difference between dead and living matter, and may we not see in a series of discontinuities of this kind a parallel with the initiation of different kinds of activity in living matter. Death would constitute as it were the master discontinuity or group of discontinuities following which the history of the organism would go on according to the ordinary continuous laws of physics without the occurrence of any further discontinuities of the kind under discussion.

The secret of the greater chemical activity of living protoplasm as compared with dead protoplasm would be sought not in any difference in the laws of chemical activity when extended to their detailed specification in terms of atomic processes, but to a difference in the state of the system resulting from considerations of the kind I have sketched. In speaking of chemical action in this connection, I desire to emphasize the extension to an interpretation in terms of ultimate or atomic processes, because if we confine ourselves to chemical laws as stated in crude macroscopic form we may well include in their formulation statements

such as would deny to a certain chemical reaction the possibility of its having more than one rate. To cite a parallel situation, a primitive statement of the laws of impact of billiard balls which treated them as perfectly smooth, elastic spheres would deny the possibility of certain phenomena which arise from the more detailed consideration of their actions in relation to the roughness of their surfaces or the rise of temperature which they may suffer at impact.

In the case of the chemical processes associated with living and non-living matter the thought is that, if we could view the chemical processes in each case in terms of the ultimate atomic processes, we could understand them both in the sense that they would obey the same ultimate laws. There would, however, be certain differences in the configuration of the system, conditions in every way consistent with the previous states in each case, but of such a kind that one could never evolve out of the other by an evolution controlled by the continuous law. We must guard against a temptation to believe that on account of the huge complexity of animal organisms they all necessarily go through all states which the general law would permit. I have only to remind you that the ultimate elements of which the matter is composed do not lose their identities in the complexity of the organism. A certain characteristic state may, while operating by continuous processes through the general law, impress itself on the whole organism without getting lost in the complexity of the organism, just as, in the hodge-podge of the city dump, the individual electrons and protons of the atoms retain their relation sufficiently to permit the permanence of the elements which they compose. They do not get lost sufficiently ever to form a new element which was not to be found in the dump originally.

One of the most astonishing things in biology is the handing on of minute characteristics such as a crooked finger or a pointed nose from generation to generation; and the fact is still more astonishing when we realize that at one stage in each generation the potentialities of each of these characteristics are contained in the apparently simple structure of the germ cell. It is only by enhancing the importance of a dependence of characteristics upon the particular system as distinct from the general laws which all the systems follow that we are able to understand the remarkable perpetuation of the characteristics shown by a study of heredity.

If now I proceed to trace the possible consequences of some of the foregoing conclusions in some of their major aspects, I fear I shall incur the censure of certain of the orthodox. We know that certain abnormal developments which take place in the human

body are to be traced to abnormal types of cell division whose initiation is not very clearly understood. Indeed, I believe I am correct in stating that the initiation of normal cell division is not very thoroughly understood. At any rate, we have, in the cases of which I am speaking, at least two different types of development, the normal and the abnormal. On a view which associates vital phenomena with the discontinuities of which I have spoken, either one or the other process of development may occur. The fact that the normal development takes place more frequently than the other is simply a consequence of the fact that the probability of occurrence of the type of discontinuity associated with that development is greater than the probability of occurrence of the discontinuity associated with the abnormal type of development. It is, of course, quite within the realm of reason to suppose that the relative probabilities of the two kinds of discontinuities might be affected by the physical or chemical state of the system—put crudely, the probability of disease is a function of the state of health of the body. Moreover, it would not be inconsistent with logical reasoning to admit that the relative probabilities of the two types of development might be controlled by the state of the system as determined by the discontinuities in the brain which we associated with thoughts, so that even the faith healer might find some basis in scientific fact for the results of the exercise of his art.

Cell division may be artificially initiated by injury; and even if I should bring it about by means of a knife, the action is one originating in the thought associated with my intention to perform the injury, and differs only from the apparently more subtle phenomenon associated with the partly unknown processes in the spectacularness of its nature.

I have no desire to force the facts in this connection, but simply to state that if the facts exist they will find their place in an extended idea of the nature of physical laws of the kind I have sketched. Perhaps a theory of faith healing based upon such a concept as I am discussing would be less open to orthodox objection than would be the more fanatical claims of the over-confident. For it is the essence of our present line of reasoning that merely the probability of the action one way or the other would be the thing that was affected. The difference between that kind of a faith cure in which a man keeps fit by not allowing himself to become depressed and that in which some one claims that he has, by meditation, mended one of his bones which had become broken, is that the former class would be one in which the probabilities of the occurrence of the different kinds of discontinuities concerned were greatly influenced

by the state engendered by the thought, while in the second class the probabilities concerned would be influenced to an unimportant degree by the corresponding mental activity.

In speaking of probabilities of occurrences, physicists are familiar with the statement that once in an eon it may happen that a piece of ice placed in a furnace will cause the furnace to become hotter while it itself becomes cooler; and the improbability of such an event has its parallel in the improbability of the effect of thought on those properties of the living organism which experience has shown to be affected to a negligible extent, if at all, by mental activity.

In principle, therefore, the possibility of the effect of thought on the probability of all kinds of development may be admitted, so that even the optimism expressed in referring to the "faith which moveth mountains" may be allowed to stand, but I fear with a very small probability factor to warrant us in relying upon it.

It may be argued that in introducing the element of chance, the element of a certain amount of unrelatedness to its previous state in the development of a system, we depart fundamentally from what, formerly at any rate, was regarded as the essence of a physical law, the prediction of the future state with certainty in terms of the past. It is well to realize, however, that even in the matter of phenomena which without question we would class as physical, in thermodynamics, in the theory of heat radiation, and in many branches of atomic theory, we have found it necessary to introduce the laws of probability, the laws of chance, into the discussion; and indeed there is much in the part played by probability in these purely physical phenomena which has a close counterpart in some of the applications I have cited in relation to vital processes.

Thus, in a system in temperature equilibrium, the radiation which passes to and fro between the different elements of matter comes, of course, from the atoms. We think of certain of these atoms as being in certain energy states from which they may pass to lower energy states with the emission of a radiation of frequency characteristic of the change of energy from one state to the other. Now statistical considerations enter in specifying the probability that any one of the atoms may be in any one of the assigned states. Then, considering all of the atoms which are in any one state, there exists a certain probability that the atom may make a change from that state to any one of several others, just as for a living organism in any one state (not necessarily characterized by its energy as in the analogue of the atom) there exists a probability that it may make any one

of the transitions which may carry it to another possible state. In the case of the atom, we are accustomed to think of the probability of a transition as composed of two parts, one depending simply upon the atom itself, and the other determined by the density of radiant energy of the appropriate frequency in the space in which it exists, this density of radiation being of course determined in turn by combined probabilities of transitions in all the other atoms. We have in vital processes a parallel to the first type in the part of the probabilities associated with some spontaneous discontinuity experienced by a living organism, and a parallel to the second type in the part of the probability which is controlled by the general state of the system or perhaps by the sum total of all the other discontinuities which are continuously taking place. To one who would complain that the introduction of statistical considerations into vital matters constitutes the invocation of non-physical processes, we must point out that here, in one of the most important fields of pure physics, in the theory of heat radiation, we have just this very type of reasoning, and one calling for as drastic a departure from the popular concept of a physical process as is involved in supposing that the physical condition of an individual may be controlled in part by his own thoughts.

But one may contend that the introduction of statistical considerations into physics is only a makeshift, pending the more complete formulation of the detailed laws in whose terms there would be no necessity for statistical considerations. It is quite true that this has been the prevailing view. Its significance can be illustrated by a consideration of the following.

Suppose that this room were covered with a flat plate of ground-glass exposed to the sky and that I had been born in the room and had never gone out of it. Suppose further that, by some optical system, the motions of the heavenly bodies had been projected on this ground-glass screen. I should know nothing about the heavenly bodies, and should confine my thought to these bright dots on my ground-glass screen. I should see them move about and should proceed to study their orbits on the screen, for I should be unconscious of any third dimension to be associated with them. You who were conscious of this third dimension would know that if I would only use it in my calculations I should greatly simplify my work, even though I should not know what it referred to and should eliminate it at the end of the work by the process of what you would call projecting the planetary motions on the ground-glass screen. But there is something more important than this.

Occasionally I should see two points of light come together on my screen and result in an explosion—you would say that a certain comet collided with a planet. On another occasion I should see two spots of light come together and nothing would happen. You would say that on this occasion one body simply passed behind the other; but, to me, "passing behind" would have no significance. I should have to be content with the statement that sometimes when two spots of light came together there was an explosion, and sometimes nothing happened. I should be driven to introduce considerations of chance, considerations of probability, into the matter, and should endeavor to impart some regularity into my observations by this means. You would, of course, know that if only I would introduce that third dimension all would be so simple. You would know that if, instead of attaching two numbers x and y to each spot of light I should attach three numbers x , y , z , I could set up appropriate laws such that an explosion would be symbolized by the equality of x_1 , y_1 , z_1 for one spot with the corresponding x_2 , y_2 and z_2 for the other. And so, in this case at any rate, the necessity of introducing statistical considerations would be the symbol of the postulation of an insufficient number of coordinates to represent our spots of light. In the last analysis, the number of coordinates which it is appropriate to attach to the entities whose relations we wish to discuss is the number of numbers which we have to attach to the individual entities in order that it shall be possible to establish relations between the numbers in such a manner as to enable us to express with certainty, *i.e.*, without leaving elements of chance, all we are interested in expressing about the system.

However, to return to the illustration in which I supposed myself to have been born and to have lived all my life in this room, the third dimension which you would have me introduce to discuss the motion of my spots of light, the third dimension which is so simple a concept to you, would be a thing of mystery to me. It would seem to me to have no reality, and predictions made in terms of it, even if I found them correct, would border in my mind on the predictions of the astrologers.

And so, while one can not say that, granting the ideas of discontinuities and considerations of probabilities in our laws as applied to vital processes, it may not be possible to reformulate the laws in a more abstract way in such manner as to avoid these probability considerations, the fact remains that the reformulation in this way might involve such a remoulding of our whole thought structure as to make the old physical laws with their discontinuities and chances provide a more satisfactory picture to our

minds than the more abstract formulation to which I have referred.

As a matter of fact, even the subconscious belief prevalent among physicists to the effect that laws of chance as introduced into their own subject were merely makeshifts for something more fundamental has, in the last two years, received a severe blow. For, in the most modern developments of atomic structure, the old idea of the universality and definiteness of the laws which control the actions of the most fundamental entity in all physics—the electron—have had to give way to laws of chance. No longer do we say that if an electron finds itself in an electric field a certain consequence will definitely follow. We say only that there is a certain probability that such and such will take place. No longer do we rest in the belief that the velocity of an electron will remain constant so long as it is not under the influence of an electric field. It may suddenly change its state of motion. From being at rest, it may suddenly decide to move about like a dog which is tired of inaction.

From the standpoint of one who admits the concept of discontinuous changes of state as an element characteristic of certain vital processes, it becomes of importance to trace the laws which govern the probabilities of occurrence of these discontinuous changes. Those changes which are not related in an obvious manner to any of the others, or to the physical state of the system, form one class, and the remainder form the other class, although it is not impossible that the difference between the two classes may be simply one of degree. Into the former class fall, of course, all those discontinuities which are to be associated with free-will actions.

An interesting problem presents itself in the possible effect of the living state upon the general laws applicable to non-living matter. I have already referred to this question in connection with the effect of life on the rate of chemical action associated with vital processes. In line with what I have already said, the influence of the vital state would not affect the continuous parts of the laws, but would concentrate itself on the introduction of discontinuities. It might well be, therefore, that those laws of the physics of non-living matter which have in the past invoked, and depended for their existence upon, the statistical aspect would be the most liable to an influence of the vital state. The most outstanding of these physical laws is the second law of thermodynamics. It would, therefore, seem particularly appropriate to test in all possible ways the conformity of living organisms to this law. Each of the consequences of the second law provides one avenue for the test, and some of these consequences concern experiments which are

possibly not incapable of application to living organisms.

When the physicist sets out to examine a new field he usually consciously or unconsciously seeks for something which is conserved. The physics of a century ago saw in mass something which was conserved. In the more recent developments, this view has had to give way as an exact statement of fact, and we now look to electric charge as the thing which is conserved in the various activities participated in by matter. The growth of the science of dynamics pointed to another entity which should be thought of as conserved—the total energy of the universe.

It is a matter of some interest to speculate on whether, as we learn more about vital processes, we shall find some measurable quantity concerned with them which may be thought of as conserved. As yet we see no candidate for the position. The number of living cells in the universe is certainly not conserved. The number of atoms forming part of living substance is not conserved. If we are to believe that life originated on our planet from non-living matter, it would seem rather improbable that we should find evidence of a conservation of anything concerned with it. And yet, it is not inconceivable that there may be some processes at work tending towards a situation in which, to use a phrase whose very vagueness is properly symbolic of the vagueness of the concept involved, a situation in which the quantity of life in the universe, or on our earth at any rate, seeks to attain a steady value.

It is by no means as fantastic as might appear to suppose that the elements peculiar to life exist at all times but in relatively insignificant amount in so-called non-living matter, so that in the sense in which we may associate life with the discontinuities of which I have spoken we may, perhaps, on rare occasions find a chunk of copper which is, in a certain sense, for an instant, alive.

One who pictures our globe in its geological antiquity may well find it hard to think of its dead substance of a thousand million years ago as having any elements of life in it. But physics presents us with strange phenomena as regards the rarity of existence of certain things and states which nevertheless play a potent part in the doings of nature.

In each cubic centimeter of this room at the present time there are about a thousand molecules which are in a peculiar state. They have lost or gained an electron. They are what are called ions. I could bring into this room a comparatively simple apparatus and measure the number of these ions in a cubic centimeter in a few minutes. Yet think how few there are of these ions in relation to the number of mole-

For in a cubic centimeter of the air there are about ten million million molecules. In other words, for every ten thousand million million molecules, only one has lost an electron. If a molecule were to go about saying that it had once seen one of its brothers which had lost an electron, it would be less likely to be believed than would the story of a miracle which had been claimed to be seen by only one person since the dawn of history. Yet these ions play a very important part in certain aspects of atmospheric electricity. Similar remarks may be made about most of the phenomena which are vital to modern physics. An X-ray is generated when an electron traveling with high speed penetrates an atom and suffers a change in its velocity. Yet, from the standpoint of the individual atoms, even of the atoms of the X-ray target, the phenomenon is so rare that if you lived on an atom you could never be made to believe that it had ever occurred. The photoelectric cell, which is responsible for the wireless transmission of pictures, owes its action to the effect of light in ejecting electrons from the atoms of a sensitive potassium surface on which it falls. Yet, if you lived on one of the atoms of the layer of potassium, it is probable that you could never be persuaded that such an emission of an electron had ever occurred, so rare is the phenomenon to the individual atom.

And so the fact that vital phenomena do not make themselves immediately evident in so-called non-living matter is no criterion as to the certainty of their complete absence. It is, in fact, not inconceivable that the existence of completely non-living matter as such would be unstable, and that the living activity might increase, perhaps slowly at first, but possibly at an increasing rate, until, at any rate in the presence of suitable conditions and environment, it finally attained a steady state in which there was a definite equilibrium between the living and the non-living matter.

In bringing to a conclusion a lecture which, I realize, many of you will consider highly speculative, I will utter one word of warning to the effect that before we make a statement that such and such a type of phenomenon would be inconsistent with physical principles, we should first weigh with care the question of what we are going to exclude under the head of non-physical principles. For, in these days of such radical developments of the abstract point of view in physics itself, it may well be that, if he is not careful, the biologist will seek to be more materialistic than the physicist would ever dream of being, and will bar from his realm of philosophy as unphysical, doctrines far less revolutionary to the thought of fifty years ago than those which the physicist himself has found

it necessary to admit in the fields of his own immediate interests.

W. F. G. SWANN

BARTOL RESEARCH FOUNDATION OF THE
FRANKLIN INSTITUTE, PHILADELPHIA

FRACTURES AND FIORDS IN THE FAEROES

THE Faeroes constitute an archipelago, spreading sixty-five miles east-west in the north, trailing 110 miles to the south, and including over twenty islands which have been carved out of an upstanding part of the vast Thulean basalt field of the northeastern Atlantic. They have been beautifully mapped by Danish topographers on seventy-two sheets, 1:20,000, and on two sheets, 1:100,000. They have lately been described as to structure and form by Peacock,¹ who visited the archipelago in 1925 as a Carnegie research fellow of the University of Glasgow. The basalt flows lie about horizontal in the north, but dip 15° or 20° to the south or southeast in the south; and are estimated to have a total thickness of over thirteen thousand feet, although the highest summit now rises only 2,894 feet above sea-level. The islands have been heavily glaciated except on their highest parts, and are of massive form. They are separated by smooth and steep-walled fiords, generally trending northwest-southwest, as if consequent upon the dip of the lavas; but certain islands are incompletely divided by two opposing, collinear fiords which are continued inland in great, trough-like valleys to low, open cols. Similar cols are found in the submerged floors of the through-going fiords where they are narrowest and shallowest. The smooth fiord walls are repeatedly cut back in cirques which, according to J. Geikie, frequently open in hanging relation to the fiord level; and the discordance is in some cases over one thousand feet; but the walls are little dissected by normal side valleys, although side streams abound. The outer headlands are steepened into great cliffs by wave work.

The islands are traversed, without faulting displacement, by a system of profound, east-west fissures, which are ascribed by Peacock to torsional stresses caused by an inferred Postglacial subsidence, and on which erosion, chiefly weathering, has recently opened many a V-shaped cleft, called by the Scotch (Caithness) modification, *goe*, of the Danish original, *gjov*; over eighty *goes* are located on an outline

¹ Peacock, Martin A., "Recent Lines of Fracture in the Faeroes in Relation to the Theories of Fiord Formation in Northern Basaltic Plateaus," Trans. Geol. Soc. Glasgow, 1926-27, xviii 1-26.

map. Peacock suggests that a continuation of cleft-making erosion would eventually transform the narrow goes into open, steep-walled fiords, and therefore explains the existing fiords by long-continued ordinary erosion now advanced to early maturity on an inferred, earlier system of northwest-southeast fractures, when the plateau stood higher than now. This explanation, in which glacial erosion is minimized, is difficult to accept in view of the abundant evidence for strong glacial erosion found in various deglaciated mountains; and as Peacock's paper proposes to discuss "the theories of fiord formation," his summary rejection of their glacial origin is unsatisfying. It may be fairly urged that the small amount of erosion by side streams in the walls of the Faeroe fiords, noted below, is of itself strongly suggestive of their excavation by ice; for had the fiords gained their present width by ordinary weathering and washing of fracture-guided goes, the abundant side streams would have cut equally abundant side valleys, because side-stream erosion is more rapid than interstream weathering; but side valleys are practically wanting in these massive islands. In this respect the Faeroes are very unlike the Pescadores in the China Sea, which also consist of nearly horizontal lava flows, but which in the absence of glacial erosion are now reduced by ordinary erosion to elaborately dissected, ragged residual masses. Ancient fractures systems, trending northwest-southeast, may truly, if they ever existed, have guided stream erosion in excavating normal valleys below the initial basalt surface in Preglacial time, but the present form of the islands appears to be much more largely due to the widening and deepening of shallow Preglacial valleys of whatever origin by energetic glacial erosion than to any other agency.

Peacock's reasons for dismissing glacial erosion as incompetent to sculpture the Faeroes appear to be as follows: First, because glacial erosion has never, to his knowledge, been invoked as the main agent for the production of the Faeroe fiords; yet over a quarter century ago it was concisely said, on the basis of the large-scale maps, that the Faeroe fiord-trough slopes "are notably smooth, unravined by the numerous streams that descend from the uplands, and hence it may be concluded that much of the dissection of the lava plateau was accomplished by ice action."² Second, because James Geikie concluded in 1883 (before the more recent understanding of glacial erosion had been reached) that the Faeroe glaciers faithfully followed the Preglacial topography of the islands; but this conclusion can not be now regarded as well supported, in so far as it excludes strong glacial modi-

fication of the Preglacial valleys. Third, because Professor J. W. Gregory, of Glasgow University, regards the Faeroe and other fiords as of Preglacial date, and as "having their ultimate origin in networks of fractures, produced by the upheaval of the earth's crust in late Miocene and Pliocene times," but this view, although accepted by Peacock as "firmly established," has not found general acceptance among students of deglaciated highlands. And perhaps fourth, because Peacock himself is not familiar, as far as one may judge by his essay, with the enlarged and over-deepened valleys of the Alps and other deglaciated mountains, or with the compelling evidence by which the enlargement and over-deepening of such valleys is ascribed to glacial erosion.

It may be added that, if glacial erosion be accepted as the chief process of fiord production in the Faeroes, the east-west fractures that are now followed by the cleft-like goes need not be regarded as of Postglacial date, although the goes themselves are evidently enough due to Postglacial erosion localized by fractures in the strongly ice-carved island masses; also, that as glacial erosion is competent to excavate fiords well below sea-level, the Postglacial subsidence of the archipelago, assumed by J. Geikie and accepted by Peacock, is not necessary in accounting for the present separation of the islands.

W. M. DAVIS

HARVARD UNIVERSITY

SCIENTIFIC EVENTS

THE FAUNA OF THE BRITISH EMPIRE

THE need for the provision of more reserves for the protection of wild animal life was emphasized at the general meeting of the Society for the Preservation of the Fauna of the Empire, which was held on October 9 at the offices of the Zoological Society, Regent's Park. According to the report in the *London Times*, Lord Onslow, who presided, said that the membership had doubled during the past two years.

Mrs. Mary L. Jobe Akeley, widow of Mr. Carl Akeley, the American naturalist and explorer, who accompanied her husband to Africa in 1926 as secretary of the expedition of the American Museum of Natural History, showed a number of lantern slides of scenes in the Kivu Parc National in the Belgian Congo, which, she said, was due to the initiative of King Albert. The park comprised an area of uneconomic territory of about 6,000 square miles, half of it consisting of a mountainous region of active volcanoes, and half of sand and swamp, abutting on the Uganda border. It was a realm of exceptional

² SCIENCE, xvi, 1902, 915.

variety in flora and fauna, and of extraordinary geological and geographic interest, and it provided an almost unique opportunity of saving some of the primitive African pygmies, a race now threatened with extinction, as well as the gorillas that inhabited some portions of it, the latter sometimes found at altitudes in the snow areas. The park in the Belgian Congo and the Kruger National Park, South Africa, were only the first links in what they hoped would become a chain of nature sanctuaries extending throughout Africa.

Dr. J. M. Derscheid, secretary of the Belgian Committee for Nature Protection, describing life in the Belgian Congo reservation, said that there were only about 300 pygmies left in that region, some 200 of whom he had seen. They were braver than negroes and not as treacherous as bushmen, and he had accompanied groups of them on their elephant hunts with spears. He added that he would like attention directed to the undue slaughter of elephants throughout Africa.

Mr. T. R. Hubback, honorary game warden in Malay, said there were three reservations in the Federated Malay States; Gunong Tahan, 360,000 acres; Krau, 130,000 acres; Sungei Lui and Seriting, 110,000 acres. It was proposed to extend the first of these by incorporating a part of the adjacent mountainous region. All forms of fauna found sanctuary within those reserves, where also refuge had been found for a wild aboriginal tribe, the Panggan.

The executive committee of the society, in their report, stated that representations had been made to the Governor of Kenya suggesting the desirability of creating national parks on the lines of the Kruger National Park, in view of the fact that a portion of the Northern Game Reserve is being alienated and that apprehensions are felt as to the ultimate status of the southern reserve.

Through the Colonial Office the society had expressed the hope that the forest reserves of Nigeria might be made also reserves for the indigenous fauna. In South Africa attention had been focused upon Zululand, which was important by reason of the fact that the last few remaining southern white rhinoceroses, probably not more than 20 in number, were found there. The area they inhabited, about 150 miles, was coveted by settlers, and in consequence the animals were being poached, one being shot last year by a settler, and about a month ago two others were found shot by unknown persons. The government and the public opinion of South Africa were fully alive to the urgent need of saving the animals, but opinion was divided as to whether they should be captured and transferred to the Kruger National Park, which

would involve transport by road and rail for 700 miles, or whether they should be protected *in situ* by a special staff. The former plan was most favored, and anybody who could suggest a workable plan of capture without much risk of damage to the animals would earn the gratitude of wild animal lovers.

In Ceylon, where the position was described as not satisfactory, the Governor, Sir Herbert Stanley, had consequently been asked to keep a sympathetic eye upon the fauna.

The committee was also taking steps to lessen the slaughter of wild animals in India, where recent legislation had placed firearms within the reach of many irresponsible persons, resulting in the threatened extinction of many species. The committee noted with satisfaction the stoppage of the wholesale capture of orang-utan in Dutch East Indies.

A NEW CALIFORNIA WILD-LIFE REFUGE

By executive order, President Coolidge has created the Tule Lake Bird Refuge in northern California, thus bringing to eighty the number of wild-life reservations administered by the Bureau of Biological Survey. The new refuge consists of 10,300 acres of government lands in northeastern Siskiyou County, within the Klamath irrigation project. These lands are flooded to a considerable extent by waste water and thus form an excellent waterfowl resort.

Paul G. Redington, chief of the Biological Survey, in commenting on the establishment of this project, states that it is a most important addition to the list of wild-fowl refuges established by executive order and by acts of Congress. Tule Lake has long been the Mecca for such wild fowl as the mallard, redhead, ruddy duck, cinnamon teal, avocets, stilts and other shore birds. It also is a favorable wintering ground for the cackling goose, a bird that breeds on the northwest coast of Alaska.

The layout of the area is such, due to mud conditions along the shores, that a natural refuge has existed in the northern part of the Tule Lake area, but sportsmen have in the past found their recreation on other portions of the area. In order not to mete out undue hardship to these sportsmen, it was deemed advisable to allow a continuance of hunting privileges on an area at the southern end of the lake, and accordingly the Secretary of Agriculture on October 10 approved an order permitting hunting on 2,800 acres south of the line forming the north boundary at sections 33 and 34 of township 47 north, range 4 east, Mount Diablo meridian. The inviolate refuge, therefore, comprehends 7,500 acres of land extremely valuable for resting and feeding grounds for the birds which frequent the area.

Mr. Redington further states that this refuge, which lies just south of the California-Oregon line, will supplement the Clear Lake refuge in California, just east of Tule Lake, and the recently established upper Klamath refuge, on the west shore of Klamath Lake, in Oregon. A year ago it was announced that because of lack of water a reflooding program on lower Klamath Lake, west of Tule Lake, would have to be abandoned. The establishment of the refuge, therefore, on Tule Lake will, in a measure, offset the loss of possible sanctuary caused by the abandonment of the lower Klamath project.

It is further stated that because of the encroachment of industrial and agricultural development the wild fowl have in many areas throughout the United States lost their former homes and stopping places, and that the government in its obligations under the migratory bird treaty with Great Britain is steadily working for the reestablishment of suitable water areas so that the wild fowl may regain something of what they have lost. The setting aside of such areas strategically located along the principal lines of migration will probably do more for the future welfare of the wild fowl than any other one measure.

SUMMER MEETING OF THE AMERICAN SOCIETY OF PLANT PHYSIOLOGISTS

At the invitation of the Purdue section, the summer meeting of the society was held at Purdue University, Lafayette, Indiana, on September 4 and 5. About fifty were in attendance, mostly from the states of Ohio, Michigan, Illinois, Indiana and Wisconsin.

On September 4, a program of short papers was given by members of the Purdue staff, explaining investigations and field plot work. Mr. J. F. Trost discussed the response of corn hybrids to fertilizers. Mr. L. P. Miller gave the results of his studies on the effect of manganese deficiency in sand culture. Dr. E. B. Mains reviewed the results of studies concerning physiologic specialization in the rusts. Mr. K. D. Doak gave the results of his investigations concerning the effect of mineral nutrition on the rust reaction of wheat. Dr. J. H. MacGillivray summarized the results of his studies concerning tomato quality. Professor L. P. Cullinan and Mr. J. L. Sullivan gave the results of their studies concerning the nutrition of apple trees. Professor P. H. Brewer described methods for the purification of the virus of tomato mosaic. Mr. L. M. Bushnell described the dominant soil types in the vicinity of Lafayette. Professor S. D. Conner outlined the agronomy field plot experiments. Following a dinner held at Lincoln Lodge, Dr. C. A. Shull discussed the present status of the journal and plans for its future development.

September 5 was spent in field trips. In the morning the soils and crops experimental farm east of Lafayette and the animal husbandry farm north of West Lafayette were visited and breeding and fertility experiments with corn were studied. Following a lunch at the Fowler Hotel, Professor E. J. Kraus discussed the relationship of plant physiology and applied botany. In the afternoon the orchards of the horticultural department west of Lafayette were visited and pruning and fertility experiments were studied.

APPROPRIATIONS FOR RESEARCH AT CORNELL UNIVERSITY

THE Heckscher Foundation for Research at Cornell University, on recommendation of its council and the approval of the University Board of Trustees has appropriated \$70,294 for forty-two separate research projects to be conducted this year.

This year's use of the income of the fund which Mr. August Heckscher established at Cornell in 1920, marks a departure from the previous policy. While providing for research in the physical and biological sciences as well as the humanities, the major portion of this year's funds will be devoted to researches in the general field of radiation. Some of the researches thus provided for are purely physical studies of the nature of radiation, some make use of radiations of various kinds in studies of the structure of matter and some deal with the effects of radiation on chemical reactions and on certain biological phenomena.

In addition to the previously announced researches in the field of radiation, the following grants in the natural and exact sciences have been made to members of the Cornell faculty for the current year:

Professor J. Papish. The occurrence, distribution and association of the rarer chemical elements.

Professor A. C. Gill for a petrographic investigation of the Tully limestone.

Professor J. B. Sumner for materials and assistance in connection with a study of the preparation and properties of crystalline urease.

Professor J. A. Dye for materials and assistance in a study of tissue respiration and endocrine functions.

Professor G. C. Embury to aid him in his studies of the rate of growth of wild trout in streams.

Professor Cornelius Betten for aid in the preparation of a manuscript dealing with the Trichoptera.

Dr. Grace H. Griswold for assistance in the preparation of a manuscript on chalcidoid parasites of aphids.

Professor L. H. McDaniels for assistance in a histological study of the phloem tissue of woody plants.

Professor Allan Nevins for assistance in a study of the history of American railways.

Professor J. C. Needham for assistance in his study of the Ephemeroidea and other Neuropteroid insects.

Professor O. A. Johannsen for the study of the development and biology of Diptera.

Professor O. F. Curtis for the study of the movement of materials within a plant.

Professor H. Ries for an investigation of the moulding sand resources of the United States.

Dr. G. H. Maughan for a study of the effect of radiant energy on the development of certain glands of chickens.

Professor H. S. Liddell for assistance in his study of conditioned reflexes in the sheep and goat.

SCIENTIFIC NOTES AND NEWS

THE twenty-fifth award of the John Fritz Gold Medal has been made to Mr. Herbert Hoover and will be presented to him at the annual meeting of the American Institute of Mining and Metallurgical Engineers in February. The citation accompanying the award reads: "To Herbert Hoover, engineer, scholar, organizer of relief to war-stricken peoples, public servant."

By vote of a committee representing the Society of Chemical Industry, the American Chemical Society, the Société de Chimie Industrielle and the American Electrochemical Society, the Perkin Medal for 1929 will be awarded to Dr. E. C. Sullivan. The award is for his work on various special types of glasses including pyrex. Presentation will be made on January 4 at a joint meeting of the chemical societies to be held at the Chemists' Club, New York.

IN the house on Twentieth Street, New York, where Theodore Roosevelt was born seventy years before, the Honorable Charles Evans Hughes and Dr. Frank M. Chapman received on October 27 Roosevelt medals for distinguished service in American public life. A third medal was accepted on behalf of Colonel Charles A. Lindbergh. The citation of Dr. Chapman said in part that the ornithologist was a "writer and lecturer of persuasive charm, who has taught a nation to see, to know, to love and to protect the entrancing and forever mysterious familiars of its daily life."

THE new Welch Medical Library of the Johns Hopkins University, named for Dr. William H. Welch, who returned recently from Europe, will be opened in a few weeks. President Goodnow has announced the appointment of Lieutenant-Colonel Fielding H. Garrison, of the library of the Surgeon-General's office in Washington, as consulting librarian. William G. Shules is named assistant librarian.

THE laboratory recently established at the Massachusetts Institute of Technology for research in in-

organic chemistry has been named the Henry Paul Talbot Laboratory in honor of the late Professor Talbot. A portrait presented by Mrs. Talbot, who was present at the ceremony, was unveiled when the new laboratory was named. Dr. F. K. Keyes, director of the laboratory and in charge of the department of chemistry, presided, and Professor H. M. Smith, in charge of the division of inorganic chemistry, made an address describing Dr. Talbot's long and distinguished association with the institute and particularly his services in the teaching of chemistry. Dr. Talbot was professor in the department of chemistry from 1892 to 1927.

A MONUMENT to Louis Pasteur was unveiled on the Chicago lake front on October 27, amid impressive ceremonies in which Vice-President Dawes and the French Ambassador, M. Paul Claudel, took part. The twenty-eight-foot monument, built of Italian marble, stands at the west end of the Field Museum of Natural History. It was designed by Leon Hermant, French sculptor of Chicago.

ACCORDING to an Associated Press dispatch an impressive ceremony in memory of Captain Roald Amundsen, who lost his life while attempting to reach survivors of the wreck of the dirigible *Italia* in the Arctic several months ago, was held in the festival hall of the University of Oslo on October 25, under the auspices of the National Geographical Society. Dr. Fridtjof Nansen delivered the principal address.

THE retirement is noted in *Nature* of Professor H. F. Newall from the chair of astrophysics at Cambridge and from the directorship of the Solar Observatory. Professor Newall was on the Mathematical Tripos list of 1880 with Sir Joseph Larmor and Sir Joseph Thomson.

AT the annual meeting of the British Horological Institute on October 10, Sir Frank Dyson, the Astronomer Royal, received the first gold medal awarded by the institute.

DR. HARVEY CUSHING, Moseley professor of surgery at the Harvard Medical School and surgeon-general of the Peter Bent Brigham Hospital, Boston, has received the decoration of commander of the Order Del Sol of Peru.

LIEUTENANT-COLONEL EDWARD G. HUBER, of the United States Army Medical Corps, was elected president of the honorary public health society, Delta Omega, at its fifth annual meeting held at Chicago on October 15, during the convention of the American Public Health Association. Dr. C. C. Young, of the Michigan State Department of Health, was elected

vice-president, and Dr. James A. Tobey, of New York, was reelected secretary-treasurer. The Delta Omega Society now has about two hundred members belonging to six chapters at the Johns Hopkins School of Hygiene and Public Health, the Harvard University School of Public Health, the Massachusetts Institute of Technology, the University of Michigan, the Yale School of Medicine and the University of California.

NORMAN TAYLOR is representing the Brooklyn Botanic Garden on the American-Brazilian Scientific Expedition to the Amazon, which sailed for Rio de Janeiro on October 27. Besides natural history and archeology the expedition will study chiefly for an American chewing-gum corporation, and map one of the tributaries of the Amazon rising in the Matto Grosso.

ACCORDING to a press cablegram, Dr. Erlandsen, of the department of botany of the University of Michigan, has arrived at Copenhagen aboard the Greenland government steamer *Gertrudbask*. Dr. Erlandsen has spent a considerable amount of time studying conditions in northern Greenland and will remain a month to compare his results with material accumulated by the botanical museum of the University of Copenhagen.

P. ARNE HANSEN has arrived at Geneva, N. Y., to join the staff of the New York State Agricultural Experiment Station as assistant in research (bacteriology). Mr. Hansen received his training in the Royal Technical College in Copenhagen in the laboratory of Professor Orla-Jensen and for the past year has been in charge of the Butter Testing Laboratory in Dublin. He plans to carry on the work at the station which has been under way for some time with special reference to heat-resistant organisms.

DR. R. L. STEHLE, professor and head of the department of pharmacology of McGill University, has returned from Europe after spending the summer in visiting laboratories chiefly in Germany and Austria.

PROFESSOR W. TRINKS, of the chemical engineering department of the Carnegie Institute of Technology, recently arrived from Germany where he spent a summer studying fuels-research conditions. While his activities were confined chiefly to investigations of continuous water-gas production methods, low-temperature carbonization, and better methods of nitrogen fixation from by-product gas, he reports that German scientific men and engineers are making important advances in all branches of technical research.

DR. T. L. PATTERSON, professor and head of the department of physiology at the Detroit College of

Medicine and Surgery, has returned to Detroit after having spent the summer at the new Jacques Loeb Laboratory for physiological research at the Hopkins Marine Station of Stanford University, Pacific Grove, California. Dr. Patterson served as acting professor of physiology at Stanford during the summer quarter and also carried out a series of comparative studies on the physiology of the gastric activity in various groups of marine animals.

PROFESSOR F. H. PIKE, of the College of Physicians and Surgeons of Columbia University, spoke before the Philosophy Club of Yale University on October 19 on "The Emergence of Land Organisms: A Study of the Nervous System in its Function in Evolution."

THE twenty-fifth anniversary of the foundation of the Faraday Society will be celebrated on Friday, November 9, at a meeting at the Royal Institution, when Sir Oliver Lodge will deliver the first Spiers Memorial Lecture, on "Some Debatable Problems in Physics."

DR. JOHN A. BOWNOCKER, chairman of the department of geology at the Ohio State University since 1916 and director of the Geological Survey of Ohio since 1906, died at his home in Columbus, Ohio, on October 20, at the age of sixty-three years.

M. PIERRE HENRI PUISEUX, member of the Paris Academy of Sciences, honorary astronomer of the Paris Observatory and honorary professor in the Sorbonne, died on September 28.

PROFESSOR WALTER H. BUCHER, of the University of Cincinnati, is to give six lectures at Princeton University on "The Origin of Earth Structure," during the period November 7 to 10.

A SERIES of fifteen discourses by research specialists of Mellon Institute will be broadcast from the University of Pittsburgh Studio of Westinghouse Station KDKA during the university year 1928-29. The talks, which are to be given on Tuesday afternoons at 1:45 o'clock, will be intended especially for home managers and students of home economics. The speakers will accord particular attention to recent advances in scientific knowledge that are of practical value in home-making and housekeeping.

THE Highway Research Board's eighth annual meeting will be held December 13 and 14, at the National Academy of Sciences and National Research Council building, Washington, D. C. Topics to be discussed will include: Practical methods based upon sound research for taking care of unusual drainage and other subgrade conditions, and for methods for design of pavements; New developments in finishing

bituminous surfaces; Factors to be considered in correlation of soil and pavement conditions; Design of guard rail based upon extensive research in Pennsylvania; Properties of bituminous materials for surface treated roads; Safety on highways as affected by rural or urban conditions, degree of improvement of roadway, light or heavy traffic, increasing volume of traffic; Effect of width of roadway and various physical conditions upon carrying capacity; The Maryland aerial traffic survey between Washington and Baltimore; Methods used in promoting the financing of state highway systems; Sound economic principles in financing road improvements; Research work of the National Safety Council. All persons interested in any phase of highway development are invited to attend.

WE learn from *Industrial and Engineering Chemistry* that the offer of the Ontario provincial government to contribute a million dollars for research, if Ontario industries subscribed an equal sum, has been accepted. Some twenty-five individuals and firms have contributed one million dollars to the fund so that the Ontario Research Foundation is now assured.

COLONEL THEODORE ROOSEVELT and Kermit Roosevelt will leave on a zoological expedition for the Field Museum of Natural History on November 10. The plan is to explore the region lying northward of Indo-China, along the gorges of the Moking River and abutting the borders of Burma, Siam and Yunnan. A second party, under the leadership of Harold Coolidge, Jr., of Boston, will leave later. He will be accompanied by Dr. Josselyn Van Tyne, assistant curator of birds at the museum of zoology of the University of Michigan; Dr. Ralph E. Wheeler, of Cambridge, Mass., who will be medical officer and assistant naturalist, and Russell W. Hendree, of Brooklyn, recently returned from three years' work in South America as a zoologist. Funds for the expedition were largely donated by William V. Kelley, the president of the Miehle Printing Press and Manufacturing Company, of Chicago, and in consequence the expedition has been named the William V. Kelley-Roosevelt expedition to Eastern Asia of the Field Museum. The first part of the expedition, under the Roosevelts, will sail from New York to India. There they will assemble equipment and proceed to the Yunnan border. The Coolidge division will sail on December 22 from Vancouver.

THE dean of the University of California Medical School and the director of the extension division of the university are making arrangements to give a course of ten public lectures in San Francisco in which the history of medical science will be discussed

by members of the medical profession in San Francisco. The topics will include the ideals of the profession, problems of public health, outstanding features of medicine to-day and types of medical service rendered to the community.

ON October 17 a meeting and discussion on "Linear Measurements" was held in the Engineering Societies Building in New York City, under the joint auspices of the Museums of the Peaceful Arts and the machine shop practice division of the American Society of Mechanical Engineers. Dr. George K. Burgess, director of the Bureau of Standards, was the chairman of the meeting. Two papers were presented, one by Professor James A. Hall, of Brown University, on "The Development of Measuring Devices, Primarily Manual," and the other by Professor Earle Buckingham, of the Massachusetts Institute of Technology, on "The Development of Automatic Measuring Devices and Use of Optical Methods." There was a discussion after the papers participated in by representatives of the Bureau of Standards, the Bausch and Lomb Optical Company, Mr. Eric Oberg and others. In connection with the meeting a special exhibit of measuring devices had been installed at the museum, to which the audience adjourned. These devices were loaned by the Brown and Sharpe Manufacturing Company, Pratt and Whitney Company, Bausch and Lomb Optical Company, L. S. Starrett Company, John Bath and Company and the Bureau of Standards. This exhibit will be on view at the museum for at least a month.

UNIVERSITY AND EDUCATIONAL NOTES

PRINCETON UNIVERSITY has received a gift of \$60,000 from Mr. and Mrs. Ellis B. Earle, of Newark, which completes the \$2,000,000 campaign fund for advanced instruction and research in the physical and biological sciences. With the \$2,000,000 goes automatically a conditional gift of \$1,000,000 from the General Education Board.

At the ceremonies connected with the dedication of the chapel of the University of Chicago, Mr. John D. Rockefeller, Jr., is reported to have said: "As president of the Laura Spelman Rockefeller Memorial I am authorized to offer to the university an endowment fund [of \$1,000,000] to be known as the Laura Spelman Rockefeller Memorial fund, to be used to promote the religious idealism of the students of the university, through the broadest and most liberal devel-

opment of the spiritual forces centering in and radiating from this chapel."

DR. ALEXANDER G. RUTHVEN, professor of zoology and director of the museum of the University of Michigan, has taken up the work of dean of the school of business administration of the University of Michigan.

DR. KARL SAX has been appointed associate professor of plant cytology at Harvard University. He has been since 1920 biologist in charge of plant breeding at the Maine Agricultural Experiment Station.

PROFESSOR GEORGE ZEBROWSKI, associate in biology at Villa Nova College, has resigned to assume direction of the science department at Villa Maria College.

DR. LEON K. JONES, associate in research (plant pathology) in the New York State Agricultural Station, has been appointed assistant professor of plant pathology and plant pathologist in the Agricultural College of the University of Washington.

DR. ALBERT B. NEWMAN, research engineer of the General Chemical Company, New York City, has been appointed head of the department of chemical engineering at the Cooper Union.

DR. ROBERT RANULPH MARETT has been elected rector of Exeter College, Oxford, in succession to Dr. L. R. Farnell. Dr. Marett is known for his contributions to anthropology and has been president of the anthropological section of the British Association.

DISCUSSION

THE ISOLATION OF A BACTERIOLYTIC PRINCIPLE FROM THE ROOT NODULES OF THE LEGUMINOSEAE

GERRETSEN, Gryns, Sack and Söhngen¹ reported the isolation of a bacteriophage from the root nodules of bean, clover, lupine and other legumes. According to this report the bacteriophage was effective against most strains of the bacteria isolated from the same plant species.

Attempts by the author to secure a bacteriophage active against the organisms of the root nodules of leguminous plants, using the technic of the above investigators, were unsuccessful. In this work the filtrates from the broth cultures, which had been inoculated with the crushed nodules, were tested against proven laboratory strains of the bacteria. In no case was there any evidence of lysis even after a large number of serial passages.

¹ Gerretsen, Gryns, Sack and Söhngen, *Cent. Bakt. Abt. II*, 60: p. 311, 1923.

Recently a successful attempt was made to secure a bacteriolytic agent active against this group of organisms. In this case the filtrate from a broth culture inoculated with several crushed red clover nodules, taken from the same plant, was added to broth cultures of a strain isolated from these nodules. This strain has been tested and found to produce root nodules on red clover plants.

After three serial transfers a lytic principle was demonstrated which was active only against this strain of the organism. Complete lysis of young broth cultures is secured in about 24 hours after the addition of the lytic agent. Growth of the homologous organism on agar is inhibited by the addition of this agent.

So far, attempts to produce lysis of other strains of the red clover nodule bacteria by means of this lytic agent have been unsuccessful, even after several serial passages.

The specificity of this lytic agent is quite interesting in view of the general lack of specificity reported by other workers.

E. R. HITCHNER

UNIVERSITY OF WISCONSIN

SOME EFFECTS ON *PISUM SATIVUM* OF A LACK OF CALCIUM IN THE NUTRIENT SOLUTION

It has long been known that the addition of calcium to the soil frequently has a beneficial effect in the growing of crops. In addition to neutralizing the acid in the soil, several other functions have been ascribed to it. The aim of this study has been to determine the effect of calcium, not as to its rôle in the soil nor at the entrance to the plant, but in its effect on certain anatomical structures of the plant. In this investigation, Canada field peas (*Pisum sativum* L.) were grown in sand cultures in the greenhouse and the nutrient solutions were varied in the amount of calcium. Plants were grown for periods of five weeks and of ten weeks. To some plants starved of calcium for five weeks, there was added the complete nutrient solution and the growth was noted over a subsequent period of five weeks.

Observations were recorded as to the external aspects of stems and roots. Green weight and dry weight determinations were made on one half of the plants. After these plants were pulverized, they were tested for calcium according to McCrudden's method. Prepared sections of stems and roots were studied microscopically for diversity in appearance. These were compared with similar sections from plants grown in the soil under the usual garden conditions. Areas of tissues in cross-section were

measured with the aid of a projection microscope and a planimeter.

In plants deprived of calcium, the length of stem is less than that of plants grown in the presence of calcium; the lower leaves are chlorotic, and the upper leaves are curled and tough. Plants grown without calcium for five weeks and then with a complete nutrient solution for five subsequent weeks show a rapid recovery and assume a normal appearance, while those plants starved of calcium for this entire period die at the end of nine or ten weeks.

Both the green and dry weight of the plant decrease as the amount of calcium is decreased in the nutrient solution. Chemical analyses of roots and of stems indicate that the calcium stored in the seed is used for early growth, since the amount of calcium oxide, calculated as percentage of green weight, or as percentage of dry weight, is slightly larger in the plant starved of calcium than it is in the plant given the complete nutrient solution. As is to be expected, the total amount of calcium, calculated as calcium oxide, is slightly greater in the plants given the complete nutrient solution than it is in a similar number of plants starved of calcium.

Whether the plants are grown under the usual garden conditions, in a nutrient solution with the full quantity of calcium, or in a solution lacking calcium, the anatomical structure of the stem and of the root remains constant, or the variation is so slight as to be insignificant. The difference is in the amount of elongation rather than in the anatomical structures. Further data and a detailed explanation of these conclusions will appear at a later date.

DOROTHY DAY

MILLS COLLEGE, CALIFORNIA

THERMAL CONDUCTIVITY OF GLASSES TRANSMITTING ULTRA-VIOLET LIGHT

INCREASED knowledge of the beneficial therapeutic effects of ultra-violet light upon living organisms has in recent years led to the development of a number of glasses which transmit ultra-violet light more or less completely. It is evident that if any of them are to replace the window-glass now being used they must be very poor conductors of heat, for otherwise man might pay dearly for the benefits secured by the use of these glasses because of the greater amount of heat they would allow to escape from a room by conduction.

The thermal conductivity for a number of these glasses has been determined at the Iowa State College by Christiansen's method. It was found that for every glass tested the thermal conductivity was less than for window-glass. By the use of some of

these substitutes man would get ultra-violet radiations into the room and he would also lose less energy by heat conductivity through them.

WILLIAM KUNERTH

WILLIAM E. BERKEY

IOWA STATE COLLEGE

CACOEPISTIC SCIENTIFIC TERMS

I HAVE been much interested in the views that have been published lately in *SCIENCE* regarding the correct pronunciation of the word *research*. The art of uttering *research* with propriety is of concern to us, because the word is so very frequently used in Mellon Institute. We have always given preference to pronouncing it "rē-serch'." I have also noted the correspondence respecting the number of the word *data*. It is regrettable that some scientific writers do not regard it as plural, thereby failing to observe grammatical principles. It should be borne in mind that the singular form *datum* is a useful word that has a fixed place in scientific and technical reporting.

In this communication I wish to point out errors that are commonly made in pronouncing certain widely used chemical and medical terms. The standard of the pronunciation of scientists and professional men is all too frequently the authority of their own specialty teachers and not always the present usage of literary society and lexicography. Professional phonology, in part at least, is thus sometimes the product of fancy rather than of precise scientific practice based upon the principles of grammar. Every profession should have a sound, fully accepted orthoëpy for its specific terms.

Most pharmacists and many pharmaceutical chemists and physicians mispronounce the word *citrate* (sit'rāt) as "sī'trāt," notwithstanding the fact that, in general, they inconsistently but correctly pronounce *citric* as "sit'rik." Likewise they pronounce *salicylate* "sal'is-il-āt," instead of sal'i-sil-āt, the preferred chemical and lexicographic pronunciation. Recently we have heard a number of different chemists mispronounce *chemotherapy* (kem-o-ther'ap-e) as "kē-mo-ther'ap-e"; this cacoëpy appears to be especially popular among manufacturing pharmacists who are featuring the use of the word in their sales promotion activities.

The following are among the other ordinary chemical terms that are often pronounced incorrectly: *acetate* ("ā-se-tāt" for as'et-āt), *amino* ("a-mi-no" instead of the lexicographically preferred am'in-o), *cyanamid* ("si-a-nam-id" for si-an'am-id), *hemoglobin* ("hē-mo-glo'bin" for hem-o-glo'bin), *methane* ("mē-thān" instead of meth'ān), *piperidin* ("pip-er-i'din" for pi-per'id-in), *ptomain* ("tō'mān" instead of tō'ma-in), *purin* ("pūr-in" for pu'rin), *saligenin*

("sal-i-gen-in" for sal-ij'en-in), *stearic* ("stēr-ik" instead of ste-ar'ik), and *xenon* ("zē'non" for zen'on).

Medical terms, however, seem to be the most frequently mispronounced of all scientific words. Very few physicians, for example, pronounce *gynecology* "jin-e-kol'o-je," but say "guy-ne-kol'o-je." The former is regarded as orthoëpic by Drs. W. A. N. Dorland, E. C. L. Miller and G. M. Gould, the recognized authorities on medical lexicography, as well as by the leading lay phonologists. *Enteroclysis* is another ordinary medical word that is often mispronounced as "en-ter-o-klī'sis," instead of en-ter-ok'lis-is. Another term of entirely different meaning, *enterocleisis*, is pronounced correctly in the former way.

There are in scientific use quite a few homophones, or words having the same sound as others, but differing in meaning and generally in derivation and often in spelling. *Sitology* and *cytology* are illustrations, both being pronounced "sī-tol'o-je." If the former were in wider usage, it would be better to pronounce it "sit-ol'o-je." *Psychosis* and *sycosis* are two other examples of casual homonyms. Then we have *tic* and *tick*; *cerasin*, *ceresin* and *sericin*; *cerin* and *serin*; *cetaceous* and *setaceous*; and other groups of words agreeing in sound but differing in meaning from one another.

Much more insistence should be accorded in education to standards of diction and composition—an insistence that students of all classes pronounce and use words carefully and properly. In England the manner of a person's speech is largely influential in determining not only his social standing but also his earning capacity—the natural condition in a country where competition is more rigorous than we in America can yet conceive, but to which we shall certainly come.

W. A. HAMOR

MELLON INSTITUTE OF
INDUSTRIAL RESEARCH

"ISORROPIC"

REFERRING to the note by Professor Alfred C. Lane on "Isontic," p. 37 of *SCIENCE* for July 13, 1928, I would call attention to the word "Isorropic" given in Webster's dictionary, from which it would appear that it is compounded of the Greek words for equal and momentum. As a whole we are told it is intended to mean: "in equipoise; of equal value." An *isorropic line* in a diagram is "the locus of all points for which a specific function has a constant value."

E. M. BLAKE

BROOKLYN, N. Y.

PRICKLY PEAR CONTROL IN AUSTRALIA

IN speaking of Dr. R. J. Tillyard's paper on the "Biological Control of Noxious Weeds" in the account of the Congress of Entomology in *SCIENCE* for September 14, the writer attributed the work done in Australia on the control of the prickly pear to Dr. Tillyard. Coming in late to listen to the paper I missed the opening remarks and the explanation by Dr. Tillyard that the work was done by the Prickly Pear Board in Queensland and New South Wales under the direction of Professor Harvey Johnston, Mr. J. C. Hamlin, Mr. W. B. Alexander and, finally, by Mr. Alan P. Dodd, to all of whom Dr. Tillyard gives most glowing tribute for the excellence of their work. The acknowledgments to these men are fully set forth by Dr. Tillyard in his paper which will appear later in the Proceedings of the Congress.

GLENN W. HERRICK

CORNELL UNIVERSITY

QUOTATIONS

THE NATIONAL ACADEMY OF SCIENCES AND HARVARD UNIVERSITY

PRESIDENT CAMPBELL, of the University of California, has recently published in *SCIENCE* a survey of the geographical and institutional distribution of the membership of the National Academy of Sciences. The significance of the survey lies in the recognized standing of the National Academy as indicating the relative eminence of American men of science in the judgment of their colleagues. It is the equivalent in America of the British Royal Society. It was incorporated in 1863, during the presidency of Lincoln, with Agassiz, Joseph Henry and others among its charter members. Its membership includes scholars in mathematics and astronomy, physics and engineering, chemistry, geology and paleontology, biology and anthropology. Originally established as a means of relating scientific research to public needs, it rendered a notable service during the Great War, and was responsible for the organization of the National Research Council, through which this service has been organized and perpetuated.

As regards geographical distribution, President Campbell's survey brings out the fact of sectional segregation. Sixty-six per cent. of the academy's members live in the New England and Middle Atlantic States (including Washington, D. C.), seventeen per cent. in the Middle West and fifteen per cent. in California, leaving the South and West (excepting California) almost unrepresented. Among institutions, Harvard has thirty-five members, and is followed, in turn, by Chicago and Yale with sixteen each,

California with fourteen and Columbia with thirteen. Of the Harvard thirty-five, seven are professors in the Medical School.

Allowing for those who may be attached to the Bussey Institution or other exclusively graduate departments of the university, it is safe to say that between twenty and twenty-five of these eminent scientists are members of the Harvard Faculty of Arts and Sciences and are therefore accessible to the undergraduates in Harvard College.

The National Academy of Sciences includes only men engaged in mathematics and the natural sciences, and can, therefore, include only a fraction of the eminent scholars who are members of the Harvard faculties. These figures serve, however, to indicate the kind of opportunity which Harvard as a university-college extends to its undergraduate students. The creative scholarship of the teacher is what makes "higher education" higher than other education. It behooves universities to foster and conserve it, as it behooves students to appreciate it.—*Harvard Alumni Bulletin*.

SCIENTIFIC BOOKS

Die Säugethiere. Einführung in die Anatomie und Systematik der Recenten und fossilen Mammalia, von MAX WEBER, professor emeritus der Zoologie in Amsterdam. Zweite Auflage. B'd. I, Anatomische Teil, unter Mitwirkung von Dr. H. M. de Burlet, Prosector a. d. R.-Univ. Utrecht; B'd. II, Systematischer Teil unter Mitwirkung von Dr. Othenio Abel, Prof. d. Paläobiologie a. d. Univ. Wien. Gustav Fischer, publisher, Jena, Vol. I, 1927; Vol. II, 1928.

THE first edition of Weber's text-book on the mammalia was published in 1904, and has been of great value to both teachers and research students. Although dealing primarily with existing mammals, the treatment of extinct forms was exceptionally full and well evaluated. To students of fossil vertebrata it has been indispensable, owing to the clear, concise presentation, free use of tables and diagrams and well-balanced treatment of osteology and "soft" anatomy, taxonomy, distribution and fossil record.

The new edition, revised and enlarged, gives more extended consideration to the paleontology of the mammalia, which has been thoroughly and very ably revised and brought up to date by Professor Abel, whose brilliant researches and text-books have placed him in the forefront of modern vertebrate paleontology. The combination of the sound, conservative judgment and thoroughness of Dr. Weber's treatment of the older phase of the science dealing with modern

mammalia, brought well up to date with de Burlet's assistance and the thorough, liberal and sometimes radical review of the fossil evidence and its bearing upon the taxonomy and phylogeny of the mammalia given by Abel, appear to be well suited to the status of these two aspects of the subject. There is much that is new, as Dr. Weber points out, in our acquaintance with modern mammalogy. But its main outlines are fixed and the new evidence serves rather to confirm and settle doubtful points. Paleomammalogy, on the other hand, has been and is still advancing so rapidly and changing so much in major as well as minor features that an adequate treatment of it demands the insight and vision, the tolerance and breadth of view, the ready but provisional acceptance or initiation of new views and concepts, that we find so well displayed in Abel's work.

The student of paleontology will find in the volume an authoritative and accurate statement of what he especially needs to know about modern mammals, and a very complete and critical summary of the recent great advances in our knowledge of fossil mammals. The chapters contributed by Abel will assuredly provoke criticism on various minor and some important points. They are doubtless so intended. Only through such a process can the new knowledge be assimilated to the body of the old.

The first volume of the book, dealing with the anatomy of mammals in general, covers some four hundred pages in addition to bibliography and index. Of these more than half are devoted to the skeleton and skin, nervous and sensory systems. A rather brief treatment is given to the muscles and teeth, the reproductive system is more fully discussed, other features of the anatomy more concisely treated. These proportions are eminently suited to the needs of the paleozoologist, for whom the present reviewer feels qualified to speak. The systematic part forms a volume of 840 pages, preceded by a tabular classification and by lists of the European and North American Tertiary faunas and followed by a bibliography and index. The groups are taken up seriatim with diagnosis and discussion of the characteristic features of each, geographic distribution, taxonomy and past history.

The arrangement of the orders shows some notable differences from the previous edition, reflecting chiefly the better understanding of the relationships of various extinct groups. It is a point of interest that instead of increasing the number of orders Dr. Weber has found it advisable to reduce them from twenty-four to seventeen, making also certain significant shifts in the sequence. The Tubulidentata are wholly dissociated from the Edentate superorder and come

at the end of the ungulate sequence. The Tillodontia are shifted from a position following the rodents to the end of the Insectivora sequence. In the Ungulata we note the disappearance of the artificial Diplarthran group, and an arrangement modified from that of Schlosser, into five orders (1) Subungulata (Hyracoids, Arsinoitheres, Proboscideans and Sirenians), (2) Notoungulata (Toxodonts, Typotheres, Entelonychia and Astrapotheres), (3) Pyrotheria, (4) Artiodactyla and (5) Mesaxonia (Protungulata = Condylarthra, Perissodactyls, Ancylopoda = Chalicotheriidae, Amblypoda and Litopterna). Numerous changes and additions within each of these larger groups have been occasioned by the paleontological contributions of the last twenty-five years, and with most of them paleontologists in this country will be in agreement, at least as to relative position, although many will be disposed to assign higher rank to some of the groups.

This reviewer is much in sympathy with Weber's conservative attitude as to the scope of taxonomic groups, but would not be disposed to go so far in reducing their rank in several instances. The Multituberculates might at least be granted ordinal rank if indeed they should not be raised to higher standing. A forthcoming article by Granger and Simpson will discuss the evidence on this point. On the other hand, Chalicotheriidae are now generally regarded as a family of Perissodactyla, although Abel has adduced some plausible arguments for maintaining their separate ordinal rank. The substitution of Protungulata for the customary term of Condylarthra is open to criticism, as also the association of Amblypoda with the Mesaxonia group instead of with the Subungulata.

The new edition of *Die Saeugethiere* is cordially commended as a very thorough and up-to-date revision of this most useful text-book.

W. D. MATTHEW

Der Sauerstoff im Eutrophen und Oligotrophen See. By AUGUST THIENEMANN. Bd. IV of Thienemann's "Die Binnengewässer," E. Schweizerbart'sche Verlags-buchhandlung, Stuttgart, 1928. 175 pages, 41 figures.

LIMNOLOGISTS have been making quantitative studies of the dissolved oxygen in lakes for more than three decades, because it is such an important factor in the environment of aquatic organisms. These investigations have yielded an extensive literature on the subject, and the present volume gives a summary and general discussion of the more important results that have been obtained.

Two types of lakes are considered, namely, eutrophic and oligotrophic. Eutrophic lakes are characterized by a marked decrease in the quantity of dissolved oxygen in the lower water (hypolimnion) during the

summer period of stagnation; in many lakes belonging to this class only a trace of oxygen or none at all is found in this stratum in late summer. Oligotrophic lakes possess an abundance of oxygen in the lower stratum throughout the summer.

One of the outstanding features of the volume is the development of a formula for the computation of the total oxygen deficiency in eutrophic lakes; the author has made computations for several well-known lakes in order to illustrate his formula. The second chapter deals with the variations that take place in the dissolved oxygen content of lakes during the different seasons of the year; special emphasis is placed upon the changes that take place in the lower water in eutrophic lakes during the summer period of stratification. The variations which are found in the oxygen content of lakes in different years are considered in the third chapter; these annual variations are attributed chiefly to variations in the climatic factor.

In the fourth chapter the author presents the results that have been obtained on lakes that are broken up into bays and separate basins; in several instances cited the different basins of lakes differ very widely in character. The oxygen relations that have been found in the thermocline (mesolimnion) of eutrophic and oligotrophic lakes are discussed in the fifth chapter. In eutrophic lakes there is usually a marked decrease in the quantity of oxygen in the thermocline, but in oligotrophic lakes there is usually very little change in the amount in this stratum.

In the sixth and final chapter the author discusses the causes for the differences in the oxygen relations between eutrophic and oligotrophic lakes. These differences are dependent upon such factors as differences in mean depth, the ratio of the volume of the epilimnion to that of the hypolimnion, the shape of the lake basin and the quantity of organic matter produced by the lake. The bibliography includes fifty-eight titles.

C. JUDAY

UNIVERSITY OF WISCONSIN

SCIENTIFIC APPARATUS AND LABORATORY METHODS

A PHOTOGRAPHIC METHOD OF MEASURING PITCH*

HISTORICALLY there have been five methods used in psycho-physics and physics for determining the frequency of vibration of sound waves in speech and music: (1) Measurements made from graphic or photographic records of sound waves, involving the use of tambours, or such light levers as the Miller

* The term "pitch" is here used in the physical sense.

phonodeik,¹ Dorsey phonelescope² or Lapp undulograph.³ (2) Stroboscopic methods, notably the Seashore tonoscope,⁴ where a manometric flame, neon tube or light lever gives a flash of light for every vibration of sound, illuminating rows of holes on a disc or drum. Knowing the number of equidistant holes in each row on the drum, it is possible to determine the number of holes passing a given point per second. When the number of flashes per second is the same as the number of holes per second, those holes are seen as stationary dots due to retinal lag. (3) A combination of resonator and light lever,⁵ the light vibrating and photographing when the resonator responds to a tone. (4) The method of beats. (5) Lissajous' method.

The first of these five is an expensive and laborious task, a record of five minutes of singing requiring film costing about fifty dollars, with the measuring and graphing of the waves requiring from one hundred to three hundred hours, depending upon the desired detail of the measures. The stroboscopic methods, while serving many purposes, do not give a continuous record of the rate and form of important patterns of singing and speaking, to say nothing of the time this method requires to transcribe a song accurately. The third technique requires one resonator for each frequency, and it would require sixty of them to cover an octave in as fine units as are necessary in studies of speaking and singing. The fourth and fifth methods are dependent upon comparing two constant frequencies, which in speaking and singing rarely exist.

The method here proposed is in a sense a combination of methods one and two above. Instead of photographing the sound wave and then measuring it, the sound wave is at once measured and graphed on photographic film. The cost of the film is about one fifth that of method one above, while the labor of measurement and graphing is almost eliminated. This is accomplished by using the same synchronizing effect as in stroboscopy. The vibrating light passes through the equally spaced apertures of the rows on the stroboscopic disc or drum, being photographed on film at the other side.

If the film is stationary, and each flash of light meets a hole in the revolving disc or drum at the same position every time, dots will be photographed.

¹ "The Science of Musical Sounds," p. 78, Macmillan, 1916.

² *Journal of the Optical Society of America and Review of Scientific Instruments*, 6: 279, May, 1922.

³ *Journal of the Optical Society of America and Review of Scientific Instruments*, 7: 661-664, August, 1923.

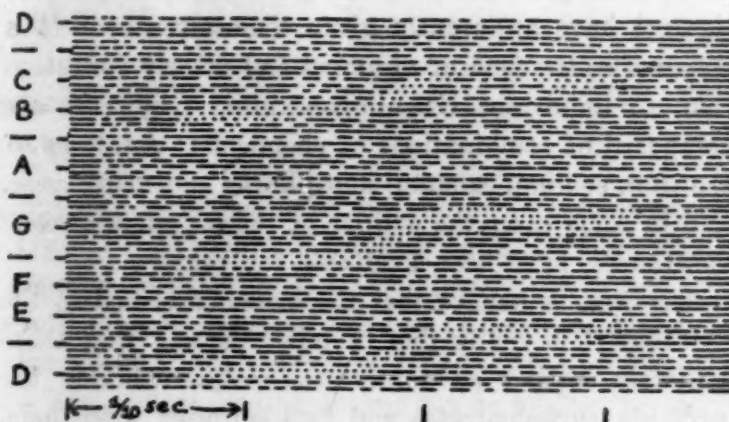
⁴ *University of Iowa Studies in Psychology*, 6: 1-12, 1914.

⁵ E. E. F. D'Albe, "The Optical Analysis of Sound," *Proc. Opt. Conv.*, 894-898, 1926.

The frequency of vibration is the same as the number of holes in this row passing a given point per second. Other rows of holes which do not meet the flashing light at the same place each time will distribute the light instead of concentrating it upon one point on the film, with dashes instead of dots resulting on the photograph.

To achieve these results, a slit which is placed between the vibrating light and the revolving disc permits each flash of light to meet one and only one dot in every row of holes. The slit is thus cut so as to be as wide as the separation distance of the holes. In the particular optical system now used there are two flashes of light for every complete vibration. To make the slit one half the size would destroy the results, since the two dots are not always one half the width of the slit described above—the relationship of these two dots varying according to wave form.

With a moving instead of a stationary film, another factor must be taken into account, namely, the speed of the film. In this case the row of holes which photographs as dots will not be the one which synchronizes with the flashing light. When the positions of two successive holes in a row on a rotating member, at two flashes of light, are the same distance apart as the film has traveled, each flash strikes the same spot on the film and therefore photographs as a dot. The same row can be used to measure two different frequencies, depending on whether the film is moving in the same or opposite direction to the holes.



A here is 870 dv. and the half step units are those of the tempered scale. The first tone actually is located at F-sharp. The dots seen above and below are not sound wave analyses, but merely are due to mechanical synchronizations at ratios other than 2:1 (flashing light with number of holes). The tones here sung by Galli-Curci have twice as many vibrations as there are holes in the stroboscopic disc.

An example of the results with a moving film is presented in the accompanying illustration, a graph of Galli-Curci's voice on two short notes photographed from a photograph record. The original photograph has been inked in order to make a zinc etching.

This method is susceptible to as many variations in devices as was the stroboscopic principle applied to the measurement of pitch, depending upon the particular needs of the research.

MILTON METFESSEL

PSYCHOLOGICAL LABORATORY,
STATE UNIVERSITY OF IOWA

SPECIAL ARTICLES

THE INFLUENCE OF MINUTE DOSES OF IODINE AND IRON ON GROWTH OF RATS FURNISHED VITAMIN A FREE DIET

IN a series of experiments recorded elsewhere, the writers have shown that while thyroid extract and iodine will produce rapid metabolism resulting in small animals, minute doses of the iodides or desiccated thyroid prove beneficial to rats on a *normal* diet and induce bone growth and increased weight. Certain preliminary experiments having shown *slight* beneficial results with sodium iodide on rats receiving vitamin A free diet, it was decided to combine minute quantities of iron with the iodine in an attempt to partially replace vitamin A.

The combination was chosen since the old-fashioned remedy, syrup of the iodide of iron, formerly so much used in anemia, has recently been displaced by the more fashionable although less esthetic *raw* and cooked liver. The peculiarity of the situation is that investigators have apparently given themselves over to a debauch in the field of vitamins and utterly forgotten that all important vitamin-containing foodstuffs are composed of combinations of chemicals. Analyses of the iron, sodium, calcium, phosphorus and manganese, and in some cases the copper of these "*vitamin rich*" substances, have been available for years.

The writers believe that the benefit ascribed to the "*vitamins*" is really due to minerals and that these minerals, acting as catalyzers, make available the proteids, carbohydrates and fats supplied with them.

One feature has been neglected in connection with discussions of the remarkable freedom from illness of those Greenland Eskimos subsisting entirely on a carnivorous diet.

The whales, seals, walruses and bears of the far north secure their food almost entirely from the water, devouring the fish which in turn depend upon minute organisms living on a diet rich in certain minerals.

The raw liver, flesh and oil of the mammals mentioned and of the codfish, which form a considerable part of the diet of the Eskimos, are rich in iodine, iron, manganese and minute quantities of other minerals such as zinc and copper. Recent investigations

by Miss Sommer and Dr. Lipman, of the University of California, indicate the significance to plants of as little as one part in two millions of either zinc or boron.

In a series of two experiments just completed (August 1) we have utilized fifty-seven rats, placing some of them at the age of one month on diets deficient in vitamin A and later using small quantities of iodide of iron to bring about a restoration to normal condition. In the first *preliminary* experiment, we used nineteen Albino rats from the original stock purchased at the Wistar Institute; in the second experiment we found it desirable to use thirty-eight Agouti rats developed from an extremely vigorous and resistant strain produced by our animal husbandry department.

In both experiments the rats were divided into four lots. The first lot received Sherman diet No. 380 plus cod-liver oil. The second lot received Sherman diet No. 380 plus 0.01 mgm of irradiated ergosterol daily. The third lot, also on Sherman diet No. 380, received in addition to 0.01 mgm of irradiated ergosterol 0.0003 grain of iodine and 0.0001 grain of iron in the form of dilute syrup of the iodide of iron. The fourth lot received Sherman diet No. 380, ergosterol to supply vitamin D and in addition a daily allowance of 0.0005 grain of iodine and 0.000165 grain of iron.

In the preliminary experiment it was noted that several rats on the deficient diet were benefited and in some cases permanently cured of their xerophthalmia. Complete growth was not resumed, however.

In the second experiment we were able to bring the deficient animals up to a point where they followed closely the average weight of the positive controls for a period of fourteen weeks.

For six weeks they remained at an average weight of twenty grams above the negative controls, fluctuating around the maximum for over three weeks. The experiment lasted twenty-four weeks.

In the absence of adequate proteid, carbohydrate and fat, we could not hope to find that minerals acting purely as catalyzers would be able to keep the animals up to normal growth. It is reasonable to suppose, however, that in the experiment that we are now running, in which we will add dextrose to the deficient diet, our minerals will show up to even greater advantage.

F. E. CHIDESTER
(In charge, Purnell Grant)
A. G. EATON
G. P. THOMPSON

DEPARTMENT OF ZOOLOGY,
WEST VIRGINIA UNIVERSITY
EXPERIMENT STATION

A GENIC DISTURBANCE OF MEIOSIS IN ZEA MAYS

DURING and following the summer of 1927, a collection of maize carrying factors for male sterility (Eyster)¹ was made for the purpose of genetical and cytological investigation. The occurrence of male-sterile plants in material from thirty or more unrelated cultures suggests the possibility of several genetic factors causing such sterility.

In segregating material obtained from I. F. Phipps, it has been found that sterility is due to a recessive mendelian factor causing irregular meiosis. In a count of 144 plants the observed ratio was 109 normal to 35 sterile plants, a deviation from the calculated ratio of but one plant.² The cytological behavior in these sterile plants has been determined by studies of the meiotic divisions in the microsporocytes.

Early stages of microsporogenesis in the male-sterile plants have not been extensively studied. During the stages just previous to and during diakinesis there is observed a partial or complete failure of synapsis. Because of this lack of synapsis and the consequent presence of a large number of univalents, metaphases are characteristically irregular. Microsporocytes most frequently show twenty univalents. Progressively fewer cells show one bivalent and eighteen univalents, two bivalents and sixteen univalents, and so on, cells with ten bivalents rarely being observed. Some anthers show a high percentage of sporocytes containing some bivalents while other anthers show a high percentage of sporocytes containing twenty univalents.

Irregularity in the appearance of metaphase I increases with an increase in the number of univalents. A microsporocyte with ten bivalents in metaphase I appears normal. When univalents are observed they do not always lie in one spindle. Usually there is one major spindle containing the several bivalents, when present, plus some of the univalents, and one to several minor spindles containing one or more univalents (Fig. 1). In consequence of the presence of several spindles, the sporocyte is divided into a number of unequal cells after the first meiotic mitosis. Each cell contains one or more nuclei and each nucleus contains one or more chromosomes. These cells undergo a second division to form microspores. It is obvious that most of these microspores and the pollen grains formed from them do not contain a normal haploid set of chromosomes, and they are probably non-functional under ordinary conditions.

¹ L. A. Eyster, *Journal of Heredity*, 12: 138-141.

² Data partly from I. F. Phipps.

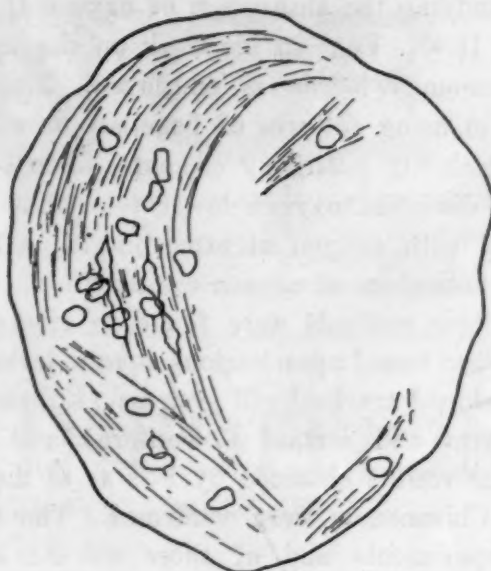


FIG. 1

This particular type of male sterility is accompanied by a certain amount of female sterility. Several pollinations have given only sparsely-filled ears. Female sterility has been observed in male steriles from a few of the other sources also. Megasporeogenesis remains to be studied in these cases.

With regard to at least one male-sterile culture, it may be stated that male sterility is due to a simple mendelian gene affecting synapsis and consequent meiotic behavior, the result being the formation of gametes containing varying chromosomal complements, only a few of which are viable.

GEORGE W. BEADLE

BARBARA MCCLINTOCK

CORNELL UNIVERSITY

THE ELIMINATION OF CARBON DIOXIDE IN THE INSECTA

WHILE carrying out experiments recently on the respiration of some of the apneustic and atracheate types of larvae found among parasitic and aquatic insects, results have been obtained which throw some light on the general subject of respiration in the Insecta, a subject as yet so imperfectly understood.

The carbon dioxide output can be studied by means of a suitable pH indicator, the larva being held motionless in a film of the fluid under a raised coverslip. The indicator must have a color change in the region of pH 7.0, easily visible, even in dilute solutions, in the thin layer underneath the coverslip. Owing to its intense color and very strongly marked change from blue to pink at about pH 6.0-6.2, a .1 per cent. solution of o-chlorophenol indophenol was found to be almost ideal and was the indicator most frequently used, the results obtained being, however, confirmed by means of phenol red, cresol red and brom-cresol purple.

For studying the absorption of oxygen the method used by H. M. Fox¹ in his work on the respiration of *Chironomus* larvae is employed. This method consists in using cultures of flagellate or ciliate protozoa which are positively chemotactic to concentrations of dissolved oxygen lower than that in water saturated with oxygen at atmospheric partial pressure, as indicators of oxygen consumption.

Both these methods were found to give consistent results when tested upon various aquatic larvae having well-developed tracheal gill systems (Ephemeroptera, Trichoptera and certain Coleoptera) and by their means the results obtained by Fox as to the respiration of *Chironomus* were confirmed. The details of these experiments and of those on the larvae of various internal parasites must be reserved for later publication.

During the course of some control experiments it was found that a well-marked reaction to pH indicators could also be obtained with the larvae of certain small Lepidoptera, such as the potato tuber moth *Phthorimaea operculella* Zell., the color change indicating a general evolution of CO₂ from the whole body surface excepting the head and posterior extremity. Further experiments showed that similar results could be obtained with other lepidopterous larvae, with larvae of certain Coleoptera, Tenthredinid sawflies, and of representatives of three families of Diptera as well as with all stages of certain Aphididae. That the effect could not be due to the contact of the indicator with the air in the mouths of the spiracles is obvious from the fact that the color change appears more or less evenly over the body surface, showing no relation to the spiracles, this also being true of amphipneustic dipterous larvae.

Experiments with pupae of Lepidoptera, Coleoptera and Hymenoptera gave varying results. In some cases a very slow evolution of CO₂ was shown, but frequently no result at all could be obtained, as was also the case with various dipterous puparia. On the other hand, the active pupae of *Culex* gave a definite reaction as was to have been expected.

Experiments with more heavily chitinized adult forms such as the Coleoptera were somewhat inconclusive owing to the difficulty of completely removing the air from the crevices of the chitin, but the indications are that although the carbon dioxide does not pass out through the heavily chitinized parts of the cuticle yet a considerable amount may be eliminated via the softer articular and intersegmental membranes. Tests so far carried out on spiders (*Argiopidae*, *Salicidae*) have given negative results.

¹ *J. Gen. Phys.*, 3: 565-573, 1920-1921.

The method is limited in application owing to the difficulty of wetting the surface of many insects, especially those with numerous wax glands or cuticular hairs, but it is certain that many if not most of those insects which possess only a thin chitinous cuticle are able under experimental conditions to liberate carbon dioxide directly through the body wall, and the writer believes that these experiments constitute the first definite evidence that this is so.

As was expected, tests so far carried out with flagellate cultures fail to give any definite indication of O₂ absorption in terrestrial insects.

The question then remains as to how far this method of CO₂ elimination is operative under natural conditions. The rapidity with which the color change appears in the indicator (from thirty seconds to three minutes in the majority of cases) and the fact that the insects are none the worse even after repeated experiment shows that the effect observed is not due to any injurious effects of the indicator solution. That the results obtained are due to CO₂ and not to any acid substance on the body surface is shown by the fact that thorough preliminary washing and repeated experiment upon the same individual tuber moth larva do not cause any diminution in the rate or extent of the color change, whereas recently killed larvae, even though unwashed, give no reaction whatever. That we are dealing with CO₂ can also be demonstrated by means of barium hydrate, although this reagent is difficult to work with and unsuitable for general use.

The work of Krogh,² Wallengren³ and others suggests that the tracheae alone are not responsible for the elimination of all the CO₂ produced and that a considerable quantity must be removed by some other means, and the work of Muttkowski⁴ has stressed the importance of the blood as a carrier of O₂ and CO₂ (probably by means of a respiratory protein), while it seems certain that in the atracheate Collembola and Protura carbon dioxide must be eliminated through the general body surface.

It may be said, therefore, that whatever may be the state of affairs in large and heavily chitinized insects it seems very probable that in the smaller thin-skinned insects, including the majority of larval forms, the tracheal system is responsible for the elimination of carbon dioxide only to a relatively small extent.

W. H. THORPE

UNIVERSITY OF CALIFORNIA,
CITRUS EXPERIMENT STATION,
RIVERSIDE, CALIFORNIA

² *Skand. Arch. Phys.*, 29: 29-36, 1913.

³ *Act. Univ. Lund.*, 11: no. 11, 1-12, 1915.

⁴ *Ann. Ent. Soc. Am.*, 14: 150-156, 1921.